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ABSTRACT

Two new designs for microfilm viewers are described. Both viewers are front projection viewers utilizing matte surface display screens. One viewer with an adjustable horizontal screen has a normal magnification rate and is mounted on a desk top. The other viewer has a high (4x) magnification rate in a mini-theater configuration with remote microfiche positioning controls. The matte surface screen is believed to be an improvement over conventional screens. Both viewers utilize conventional projection optics to maintain image contrast in controlled lighting environments. Interference between the user and the projected light is virtually eliminated by oblique projection achieved by simple, practical techniques. A survey of users shows a marked preference for the mini-theater viewer over conventional near projection viewers. Two control modes for positioning microfiche were developed for the mini-theater viewer: a velocity-control system and a position-control system. A comparison of these two modes shows that users prefer the position-control system. A survey of fiber optics, photochromic materials, and conventional optics for possible use in a small portable, and self-powered viewer shows that conventional optics with clever packaging will best meet the design needs. (JY)

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MICROFILM VIEWER EXPERIMENTS

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ABSTRACT

Techniques and concepts applicable to the design of new and appealing microfilm viewers were examined. Two front projection viewers utilizing matte surface display screens were constructed: (1) a normal magnification viewer (desktop viewer) mounted on a desk top with an adjustable horizontal screen and (2) a high (4X) magnification viewer in a mini-theater configuration with remote microfiche positioning controls. The superiority of matte surface screens for viewing displayed text material is discussed. Both viewers utilizing conventional projection optics maintain excellent image contrast in controlled lighting environments and interference between the user and the projected light is virtually eliminated by oblique projection achieved by simple, practical techniques.

A survey to test receptivity to the mini-theater viewer shows that users greatly prefer this viewer to conventional rear projection viewers.

Two remote microfiche positioning control systems were built for the mini-theater viewer: (1) a velocity-control system (stepping motor drive) and (2) a position-control system (continuous servo-motor drive). A comparison is made between these control modes in terms of cost factors, dynamics and user preference.

Fiber optics, photochromic materials, and conventional optics were examined for possible use in a small, portable and self powered viewers. It was found that coherent, tapered fiber optics are too bulky and prohibitively costly for this application. Photochromic materials were also found unsuitable for the reasons: (1) the high energy levels necessary for activation and bleaching, (2) poor imaging qualities (photochromic glass) and (3) fatigue on repeated activation and bleaching cycles (organic photochromic films). A preliminary design study of conventional optics shows that by clever packaging, a compact and self powered viewer could be made.

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CHAPTER I

INTRODUCTION

A. OBJECTIVES

The purpose of this project was to investigate and experiment with two new ways of designing microfilm viewers so as to enhance their appeal to the user community. During the course of these investigations techniques for presenting microfilm images to an observer by means of light reflected from an opaque screen were examined, and fiber optics, photochromics and conventional optics were examined for possible use in a lightweight and compact hand-holdable viewer.

Two viewer configurations utilizing a matte surface opaque display screen were designed and built. One is a high-magnification system which displays images four times actual size and is used at a viewing distance of five feet. The images are displayed on a vertical screen. The other is a normal-magnification system imbedded in a desk, with the display screen nearly horizontal. The high-magnification system, hereafter referred to as the "vertical-screen viewer", was examined to test user receptivity to a "mini-microfilm theater" concept which offers ample physical mobility and comfortable seating to the user. Furthermore, since a high-magnification viewing system can serve several observers simultaneously, its use can be extended to group applications. The normal-magnification system, hereafter referred to as the "desktop viewer", was designed to achieve maximum image quality and accommodation to personal comfort while the user is seated at a desk.

In the companion part of the project, fiber-optics technology was examined as a possibility for high-density packaging and the use of ambient illumination for viewing the microfilm, both highly desirable factors for a compact, self-powered and hand-holdable viewer. Photochromics were also examined for applicability in a hand-held viewer since the image retaining properties of photochromic materials suggested low power consumption.

B. SUMMARY OF RESULTS AND CONCLUSIONS

The normal-magnification desktop viewer was designed and constructed as shown in Fig. 1.1. The salient features of this viewer are : The matte surface display screen has virtually no limitation on viewing angle. The entire viewer, including the display screen, can be rotated and tilted to accommodate user preference. A combination of simple techniques allows an oblique projection onto the screen, thereby virtually eliminating interference of the user with the projected light. Image contrast is excellent for ambient illuminations as high as 80 footcandles and is acceptable at 100 footcandles. The manually operated film transport is convenient to load and unload. Focus is uniform and maintained automatically once preset. Operation of the viewer

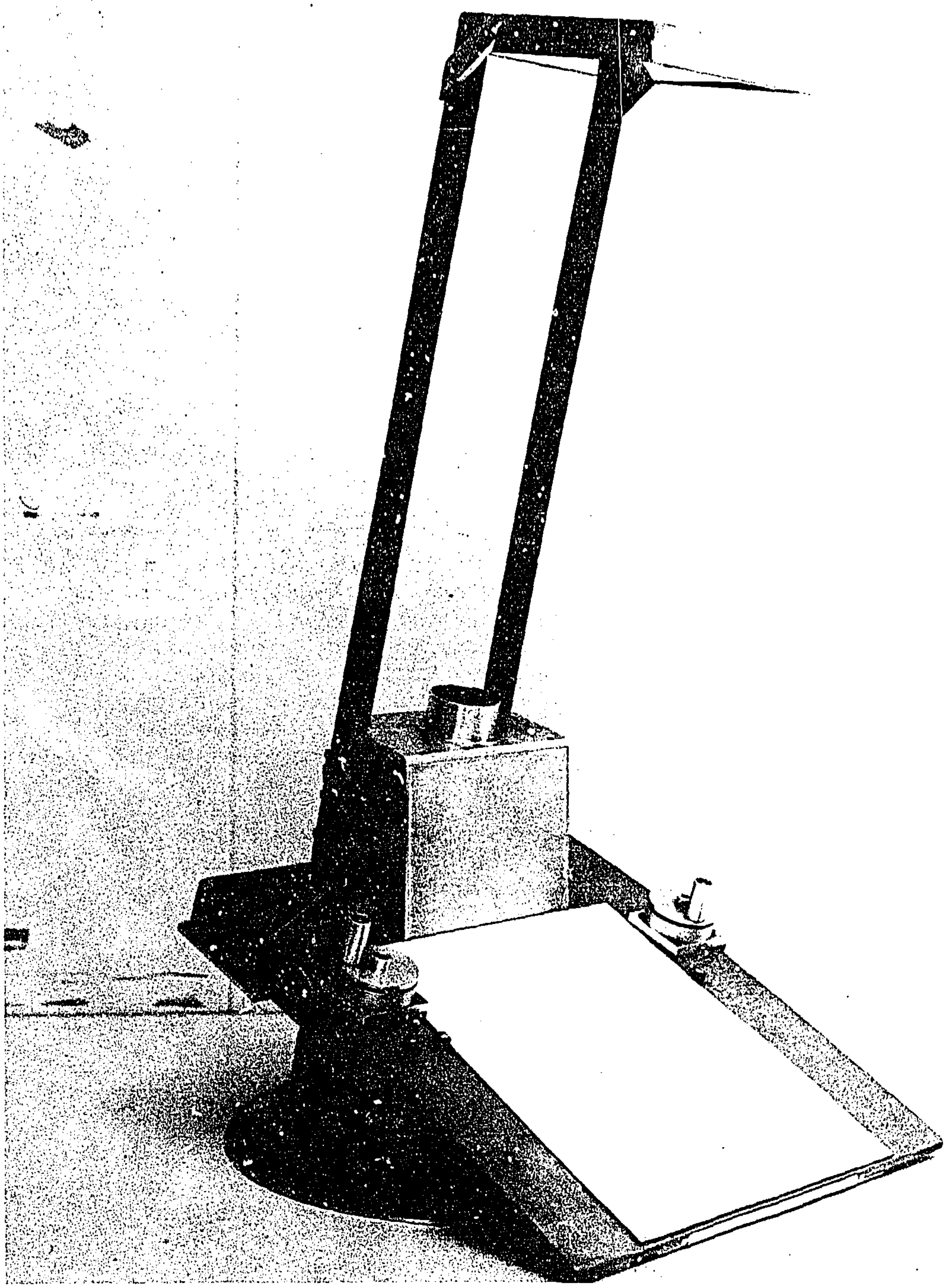


Fig. 1.1 The Electronic Systems Laboratory Desktop Viewer

by a limited sample of users indicates that this viewer concept will be met with approval and enthusiasm by a general usership.

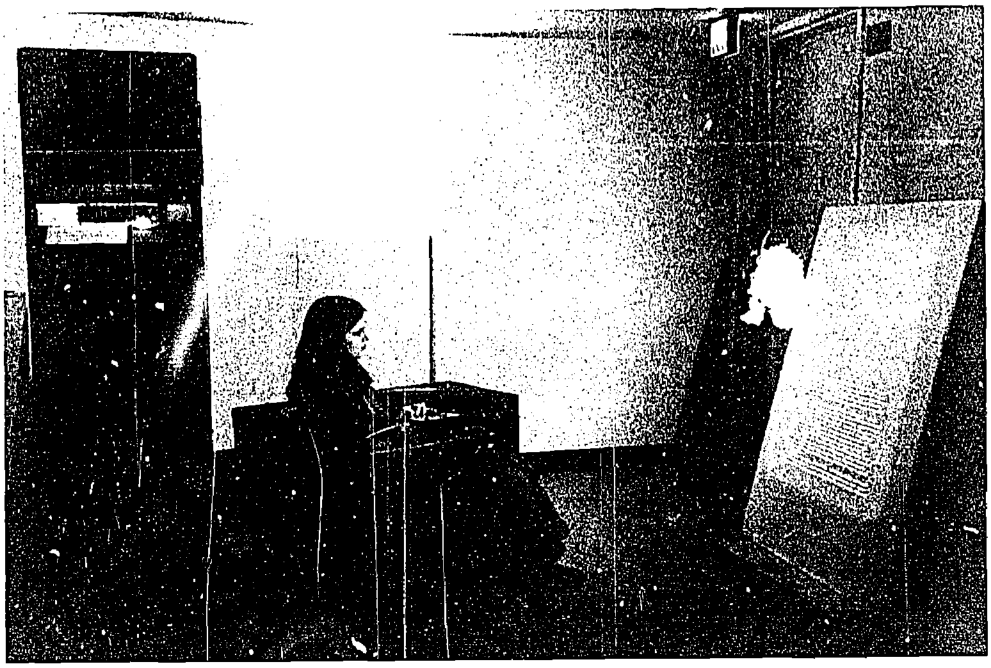
The vertical screen viewing system is illustrated in Fig. 1.2. Its essential features are: The user is seated comfortably in an "easy chair" approximately five feet from a vertical matte surface screen. Image contrast is excellent in controlled lighting environments of approximately five footcandles. Loading of the microfiche is accomplished at one side of the projection system. Two microfiche transport systems, providing the user with remote positioning and focus controls have been designed and constructed for interchangeable use and testing. One is a velocity-control system with a digitally controlled stepping-motor drive that provides the user with a choice of travel along either microfiche axis. The second system is a position-control device with a continuous servomotor drive that provides the user with a matrix of buttons representing all the frames on the microfiche. Both fiche control devices are located handily beside the user at his viewing location. Focus is maintained once preset. The floor area required is 25 square feet.

The vertical-screen viewer was installed in the M.I.T. Barker Engineering Library and has been evaluated by approximately 60 users at the time of the printing of this report. Results indicate a user preference in excess of 3 to 1 for the general concept of the vertical-screen viewer over conventional microfiche viewers. The most popular features are the comfortable seating position, the freedom of user movement that is allowed and the good image quality of the matte screen. Details of this evaluation are discussed in Section H of Chapter V.

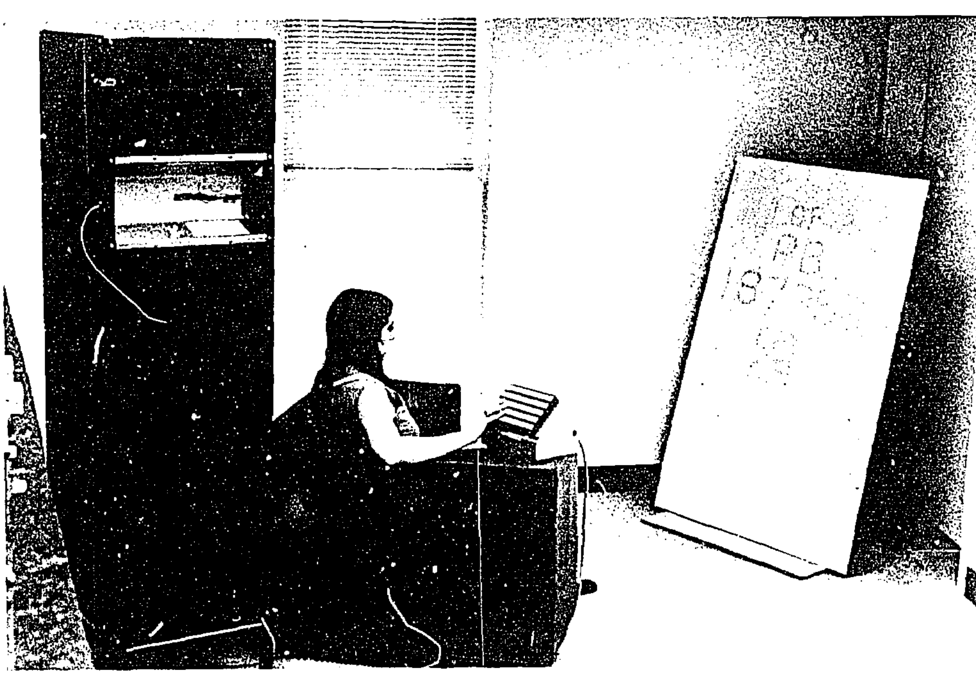
The results of the investigations into the use of fiber optics in a compact, hand-held viewer were essentially negative. It was found that coherent, tapered fiber-optics having the resolution required for use in a microfilm viewer would pose formidable fabrication problems and would be prohibitively expensive. Further, because the taper must be limited to three diameters per inch in order to prevent serious light loss in transmission, a large volume and high weight would be encountered in microfilm viewers. Finally, the directional nature of tapered fiber-optics limits the desirability of their use as a display screen.

The studies of photochromic materials for use in a hand-held viewer were equally discouraging. The photochromic materials surveyed were found to require prohibitively high quantities of energy to activate (write) and to bleach (erase) for a display screen. Photochromic glasses typically require a 3 mm thickness for sufficient contrast, which would cause the image characters to appear to have a 3 mm depth. Organic photochromic films exhibit fatigue on repeated activation and bleaching cycles.

Finally, various possibilities for a compact, hand-holdable viewer having a transmitted-light screen and powered by rechargeable



(a) VERTICAL-SCREEN VIEWER EQUIPPED WITH VELOCITY CONTROL



(b) VERTICAL-SCREEN VIEWER EQUIPPED WITH POSITION CONTROL

Fig. 1.2 The Electronic Systems Laboratory Vertical-Screen Viewer Installed at the M.I.T. Barker Engineering Library

batteries for approximately a one-hour viewing time were examined. A preliminary design study was made with special emphasis on compactness. Although the results of this study were promising, the decision was made to concentrate the efforts of the group on the design, construction and evaluation of the desktop and vertical-screen viewers previously discussed.

CHAPTER II

REFLECTED-LIGHT VIEWERS

A. INTRODUCTION

The components of a typical microfilm viewer are basically the same as those of a common slide projector, namely: a light source with associated collector optics; a projection or imaging lens; and a display screen. Display screens are passive surfaces which scatter light from an image projected upon them so that the image is visible to the observer and are generally either transmitting screens or reflecting screens. A transmitting screen scatters the light projected upon its side opposite the side the observer faces. A reflecting screen is opaque and scatters the light projected on the same side which the observer faces.

Common complaints users have against rear projection microfilm viewers have been published in the literature.[1] Among them are: non-uniformity of observed image brightness or "hotspots", restricted viewing angles, and scintillations, or small slivers of colored light observable at the screen surface. The use of an opaque, matte display screen can remove these difficulties. The advantages of matte display screens for reading purposes is discussed in Section B of this chapter. However, matte screens make it difficult to achieve good image contrast in the presence of ambient illumination, and this problem is discussed in Section C of this chapter. Furthermore, since a matte screen is opaque, a front-projection system is required, and difficulties arise because of interference of the user with the projected light rays. A discussion of these difficulties and the solutions used for the desktop and vertical-screen viewers are discussed in Section D of this chapter.

B. ADVANTAGES OF MATTE SCREENS

A major factor contributing to the pleasing quality of matte surface display screens is their complete uniformity of observed image brightness. Image brightness is essentially invariant for wide viewing angles and arbitrary sight lines. The following discussion illustrates why matte screens are desirable for wide-angle viewing or reading.

The reading task is usually performed by an observer whose eyes are 10 in. to 14 in. from an 8 1/2 in. by 11 in. page (see Fig. 2.1). For a viewing angle ϕ_0 = 0 deg, the half-angle subtended by the reading surface at the eye of the observer is the field angle, $\Delta\phi$, which is approximately 35 deg at a 10-in. viewing distance and 26 deg at a 14-in. viewing distance. If the observer moves his head laterally 12 in., the viewing angle ϕ_0 is approximately 50 deg. On the assumption that the projected light is normally incident on the

screen surface, the variation of observed image brightness over the screen surface for changes in field angle and viewing angle is described by the characteristic relative luminance curve of the screen.

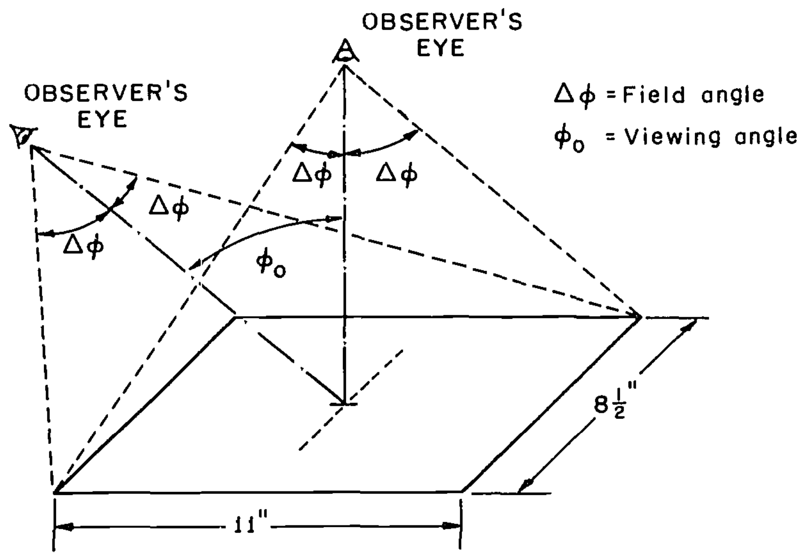


Fig. 2.1 Geometry of Reading

Relative luminance is defined as the ratio $(B(\phi)/B_{pd}$ where $B(\phi)$ is the luminance measured at an angle ϕ and B_{pd} is the luminance of a perfect diffuser (independent of ϕ) for the same normally incident light beam.

Figure 2.2 shows the normalized relative luminance curves of various types of front projection screens. In order to avoid non-uniform brightness or hotspot, the variation in brightness must be confined to 50 percent, or less, for field angles of 25 deg to 35 deg. If the further requirement is made that brightness must not vary more than 50 percent with a change in viewing angle of 50 deg, it is obvious from Fig. 2.2 that only the matte screen satisfies these requirements. For viewing distances much larger than 10 in., a head motion of approximately 12 in. would result in proportionately smaller changes in viewing angle. Magnification is varied to keep field angle constant. For viewing distances greater than 24 in., a head motion of 12 in. causes the change in viewing angle to be less than the field angle, and uniformity of brightness becomes the prime consideration. Since some screens, other than matte screens, can satisfy the requirement that the variation in brightness for field angles of 26 deg is less than 50 percent, that is, a tolerable hotspot, it might seem that these screens could be used in a vertical-screen viewer. However, the vertical-screen viewer considered here was required to

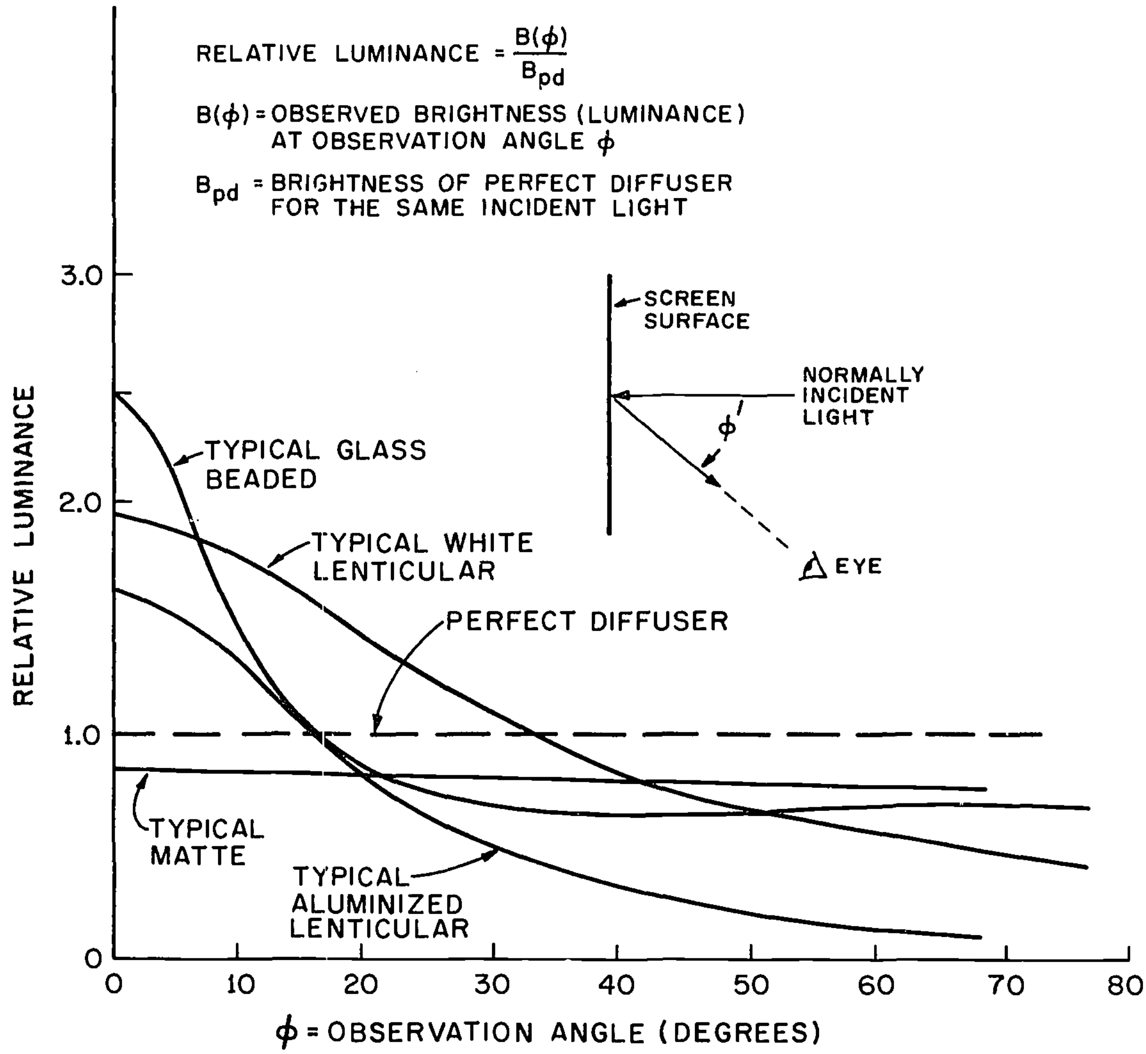


Fig. 2.2 Relative Luminance of Opaque Screens
(Data taken from Klaiber – See Ref. 2)

accommodate a group of four to six observers, simultaneously, and these observers should be able to see the image equally well. For each observer the image must be neither too big nor too small. Since the viewing distance should be of the order of 60 in. in order to conserve space and maintain contrast (see Section C, Chapter II), the observers must be confined, at most, to a two-row seating arrangement. The variation in sightline or viewing angle between the center observer and the observer seated at either end is then of the order of 40 deg. In order to insure that all the observers can view the image with approximately the same brightness and contrast, the variation in screen relative luminance should not exceed 50 percent among the observers. It should be pointed out that, for a desktop version of an opaque-screen viewer, the assumption of 12 in. of head motion is somewhat arbitrary and for the vertical-screen viewer, the flexibility of the viewer increases with its ability to accommodate as many observers as possible.

Another important characteristic of reflective screens used for reading is the nature of the surface. Screens exhibiting non-uniform angular distribution of reflected light achieve this characteristic by two typical methods: the addition of tiny refractive elements or glass beads to the scattering surface, or tiny reticulations (lentils) of the scattering surface. A survey of commercially available glass-beaded and lenticular screens lists typical variations in bead diameter as 0.1 mm to 0.5 mm, and the groove spacing of lenticular screens as varying from 0.5 mm to 1 mm.[2] Although some beaded screens have beads too small to be visible at a 10-in. viewing distance, the beads cause refractions which appear as small slivers of colored light that shift and move (scintillate) with the slightest change in viewing angle. Matte screens, however, are commonly free from observable scintillations. The grooves of lenticular screens are readily apparent at viewing distances as great as 60 in. Although these screens have limiting resolutions of 20 to 40 line-pairs/mm, they are unsuitable for reading purposes since the grooves conflict with the vertical and horizontal strokes of imaged characters. Commercially available plastic matte surface screens have resolutions of 30 to 40 line-pairs/mm, and are more than adequate for desktop and wall viewers.

C. CONTRAST

An important parameter in the design of microfilm viewers is the contrast degradation attributable to ambient illumination incident on the screen. Although ambient-illumination levels can be controlled, a premium of convenience is placed upon a microfilm viewer exhibiting satisfactory contrast in the presence of the illumination levels of 40 to 80 footcandle found in typical modern office environments. Walkup[3] et al. recommended a minimum contrast of 0.7, where contrast C is defined as

$$C = \frac{B_G - B_L}{B_G} \tag{1}$$

B_G = Observed brightness of background areas

B_L = Observed brightness of letter areas

Assuming a perfectly diffusing matte screen and a Kohler illumination scheme, we have:

$$B_G = RB_A + \frac{\pi t}{4} B_s R T_G \frac{1}{(1+m)^2 f^2} \tag{2}$$

$$B_L = RB_A + \frac{\pi t}{4} B_s R T_L \frac{1}{(1+m)^2 f^2} \tag{3}$$

where B_A = Screen brightness in footlamberts from ambient sources causing an illumination E lumens/ft^2 incident on the screen. B_A is numerically equal to E.

t = Transmission factor of optics

R = Screen reflectivity

f = Projection lens f-number

m = Magnification

B_s = Source luminance

T_G = Transmission factor of film through ground areas

T_L = Transmission factor of film through letter areas

If a quantity B_p is defined as the screen brightness with no film in the projector gate and with $B_A = 0$, then:

$$B_p = \frac{\pi t}{4} B_s R \frac{1}{(1+m)^2 f^2}$$

Contrast may then be rewritten as:

$$C = \left| \frac{B_p[T_G - T_L]}{RB_A + B_p T_G} \right|$$

Good quality microfilm can be expected to have values of $T_G = 0.85$ and $T_L = 0.1$. Figure 2.3 shows the effects of ambient illumination on contrast for selected values of B_p. A projection system equipped with a quartz halogen source (3200 deg K) and an F/4 projection lens can be expected to have a value of B_p in the range of 200 to 300 footlamberts for a screen reflectivity of 0.85 at a magnification m of 20. To achieve significantly higher values of B_p would require an arc source, which necessitates costly and bulky power supplies and poses formidable heat dissipation problems in the microfilm. Further, arc sources usually require a warm-up and stabilization time of several minutes, and then require an even longer cooling period between shutdown and re-ignition.

The curve representing $B_p = 210$ footlamberts characterizes the performance of the desktop viewer for a magnification of 10 and an F/5.6 projection lens. It can be seen that the desktop viewer maintains good contrast through the range of ambient-illumination levels of 40 to 80 footcandles. It should be pointed out that the minimum contrast of 0.7 suggested by Walkup et al. is a rather high standard; contrast as low as 0.65 is still quite acceptable.

The curve in Fig. 2.3 for $B_p = 20$ footlamberts characterizes the performance of the vertical-screen viewer. It is obvious that the vertical-screen viewer must operate in relatively low ambient illumination environments in order to maintain reasonable image contrast. Indeed, the requirement that the wall viewer operate in an environment of 5 to 10 footcandles essentially set the upper limit of the magnification at approximately 80, and consequently the user to screen distance of approximately 60 in. A 5 to 10 footcandle ambient illumination is subdued, but not dark, and is sufficient for writing while viewing.

In the desktop viewer, screen reflectivity is used to control screen brightness, since the 210 footlamberts of this viewer is somewhat uncomfortably bright. It was initially intended that screen reflectivity would be adjusted by means of quickly interchangeable screens so that the reader could match screen brightness to the brightness of hard-copy text illuminated by ambient room sources, thus minimizing eye adaptation and fatigue during note-taking or cross referencing to hard-copy text. It was found however, that most users preferred a screen brightness of approximately 80 to 100 footlamberts for the entire range of ambient illuminations of 40 to 80 footcandles. A series of screens with reflectivities 30 percent to 70 percent was prepared; the most preferred by users was 50 percent. This suggests that a single screen with a reflectivity of 50 percent can be used with a source-brightness control provided for ambient illuminations below 40 footlamberts.

One of the reasons for the widespread usage of transmitting-screen microfilm viewers is that contrast may easily be improved with

a single circular polarizing filter in front of the screen. Also, the directional properties of transmitting screens and beaded or lenticular reflecting screens minimize the effects of ambient illumination by preferentially guiding projected illumination to the observer. The matte screen, however, is the least amenable to simple forms of contrast enhancement.

Shielding devices or hoods intended to block ambient illumination were examined. Results showed that for this technique to be effective, viewing angles were severely restricted, obviating the reasons for the initial choice of a matte screen. Polarizing filters have little advantage, since modern office environments can be characterized as diffuse sources or integrating spheres. Even if room sources were polarized, most ambient illumination incident on the reading surface would have been unpolarized by multiple reflections from matte surface walls, ceilings, etc. Since a diffusely lighted office, or other interior, is generally the most pleasing to work or write in because of the lack of shadows, it seems hard to justify the direct lighting necessary to make polarization filters effective for contrast enhancement. Furthermore, polarizing filters on top of a matte screen may seriously alter the nature of the matte surface, and are subject to direct reflections. The use of color filters and colored screens necessitate unnaturally colored environments to yield significant increase in screen contrast. In any event, methods that depend on controlling characteristics of ambient illumination other than level of ambient illumination, severely limit the transportability of the film viewer. Hence, these techniques were dropped from consideration.

D. USER-LIGHT RAY INTERFERENCE

The problem of the user interfering with the projected light rays is always present in reflected-light viewing systems. A brief consideration of the problem suggests that the viewing area increases as the projection angle increases (see Fig. 2.4). If viewing angles of 30 deg to 45 deg and projection angles of 20 deg to 30 deg are assumed, interference is essentially eliminated. A horizontal screen was chosen for the desktop viewer for the following reasons: a horizontal screen more nearly coincides with common reading habits than does a vertical screen when the observer is seated at a desk; wearers of bifocal spectacles are more comfortable with horizontal screens; and observers are more tolerant of viewing angles of 30 deg to 45 deg for horizontal screens. The use of several mockups confirmed that a sightline of 30 deg to 45 deg is quite comfortable, and commonly used in reading hard copy on a desktop. Since the display screen is a matte surface with image brightness independent of viewing angle, the analogy to reading habits for hard-copy text is valid.

A combination of two simple techniques was used in the desktop viewer to achieve a projection angle of 23.5 deg. By displacement of

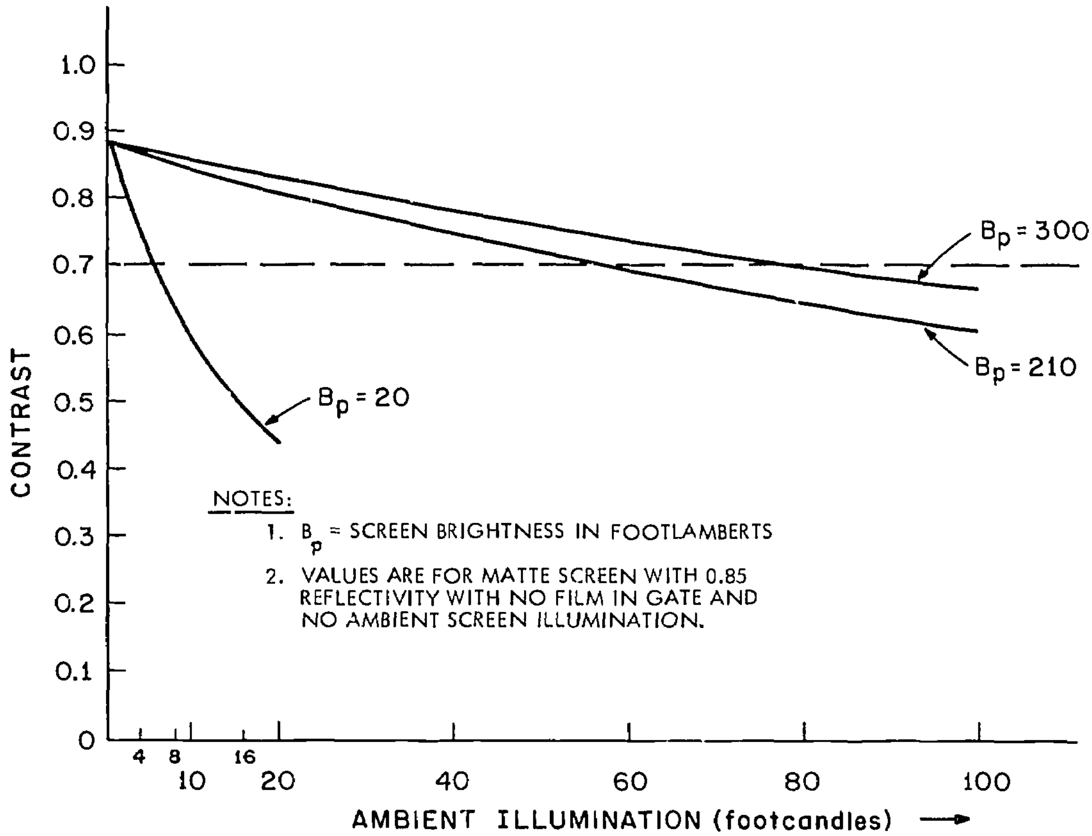


Fig. 2.3 Contrast as a Function of Ambienr Illumination

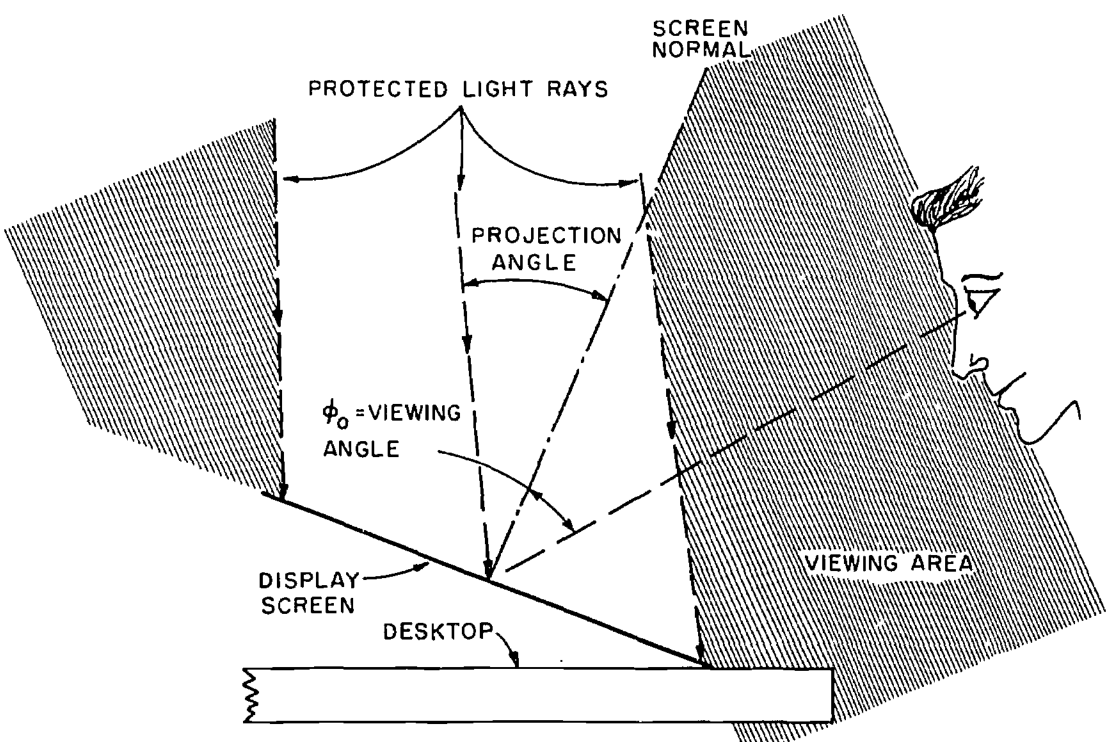


Fig. 2.4 Oblique Image Projection

the microfilm from the lens axis by an angle α (see Fig. 2.5), a projection angle of α results. This technique however is limited by deteriorating lens resolution for off axis imaging, and to maintain good resolution, a lens with a larger format area is necessary. The second technique is to tilt the conjugate planes, as in Fig. 2.6. This technique, however, produces image distortion commonly called keystoning.

The projection lens of the desktop reader has a sufficiently large format area (65 x 90 mm) to allow the placing of the microfilm image 13 deg off axis. Simple tests showed that the resolution of the lens at the format center was approximately 220 line-pairs/mm and 160 line-pairs/mm at the extreme edge of the format, indicating that image quality was only slightly reduced. Tilting the conjugate planes increased the projection angle to 23.5 deg with only $\mp$ 2.5 percent variation in magnification around the image center. Although a magnification variation of $\mp$ 3 percent is detectable, it is usually unnoticed by observers or considered acceptable.

As previously discussed, the magnification of the wall viewer was limited to approximately 80 to maintain image contrast. For a 20X reduction microfiche, a magnification of 80 represents a 4X enlargement and suggests a viewing distance of four times 10 in. to 14 in., or 40 in. to 56 in. However, preliminary results showed that most obsevers preferred viewing distances of the order of 60 in. to 70 in.; and these values were used in laying out the overall device.

The projection axis for the wall viewer must be in the vertical median plane to avoid objectionable horizontal keystoning. Studies indicated that in order for the film plane to be close to the operator (to allow convenient loading and unloading of microfiche), the only practical layout is as shown in Fig. 2.7. The low position of the screen resulted from preferences indicated by observers in early studies. A slight tilt in the screen, as shown, limits the projection angle to 12 deg and is achieved almost entirely by tilting the conjugate planes. Image quality (resolution) is good, and magnification variation is approximately $\mp$ 2.5 percent around the center of the image.

Other techniques for achieving higher projection angles with either less or no image distortions were considered, since larger projection angles would obviously afford greater design flexibility and further minimize user/light-ray interference. A number of thin-lens configurations were geometrically analyzed, and one such scheme is presented in Appendix A. These techniques can be generally described as follows: a distorted image is formed by a "copy" lens near unity magnification; a final projection lens magnifies this distorted intermediate image and introduces further but complementary distortions such that the final image is either uniformly distorted (no keystoning) or is undistorted. The analysis in Appendix A is for the undistorted case.

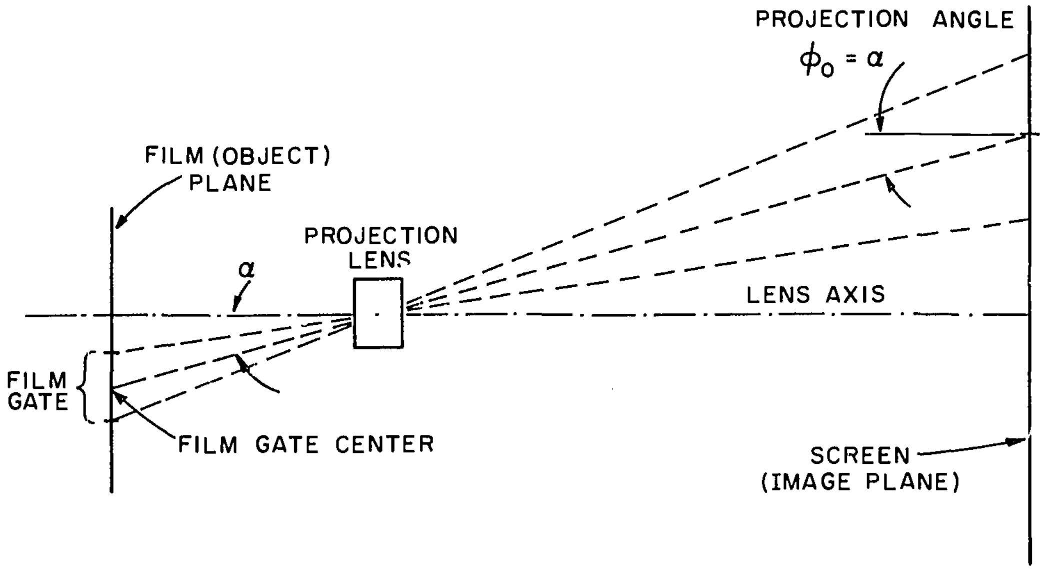


Fig. 2.5 Oblique Projection Achieved by Displaying Film Gate from Lens Axis

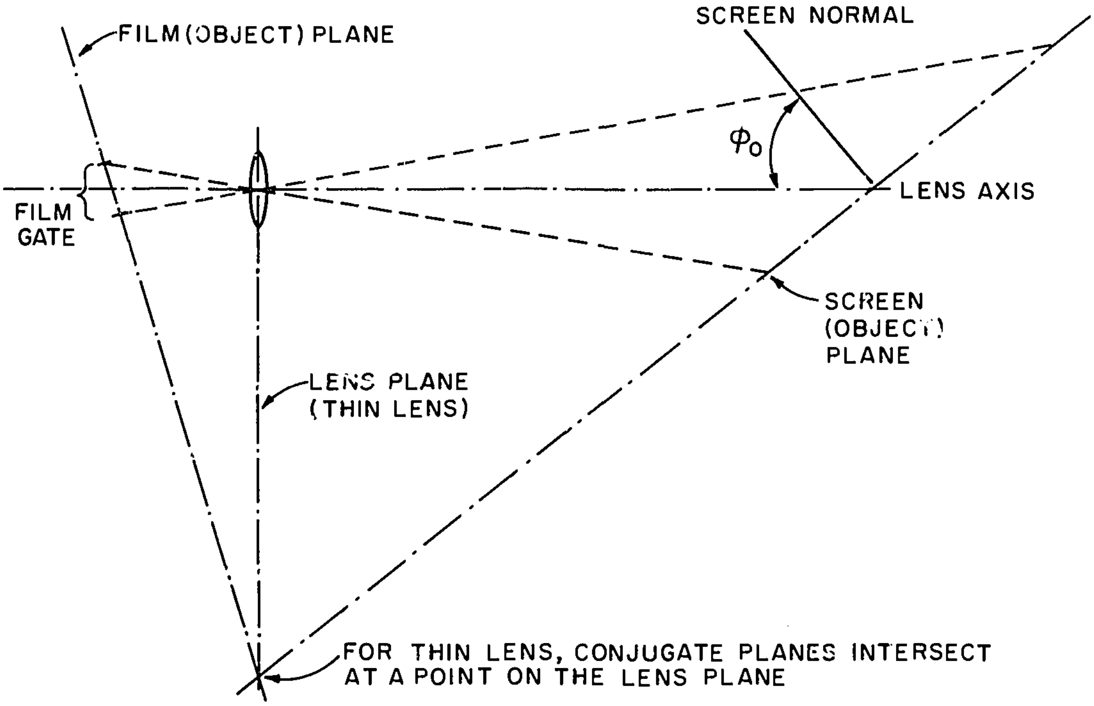


Fig. 2.6 Oblique Projection Achieved by Tilting Object and Image Planes

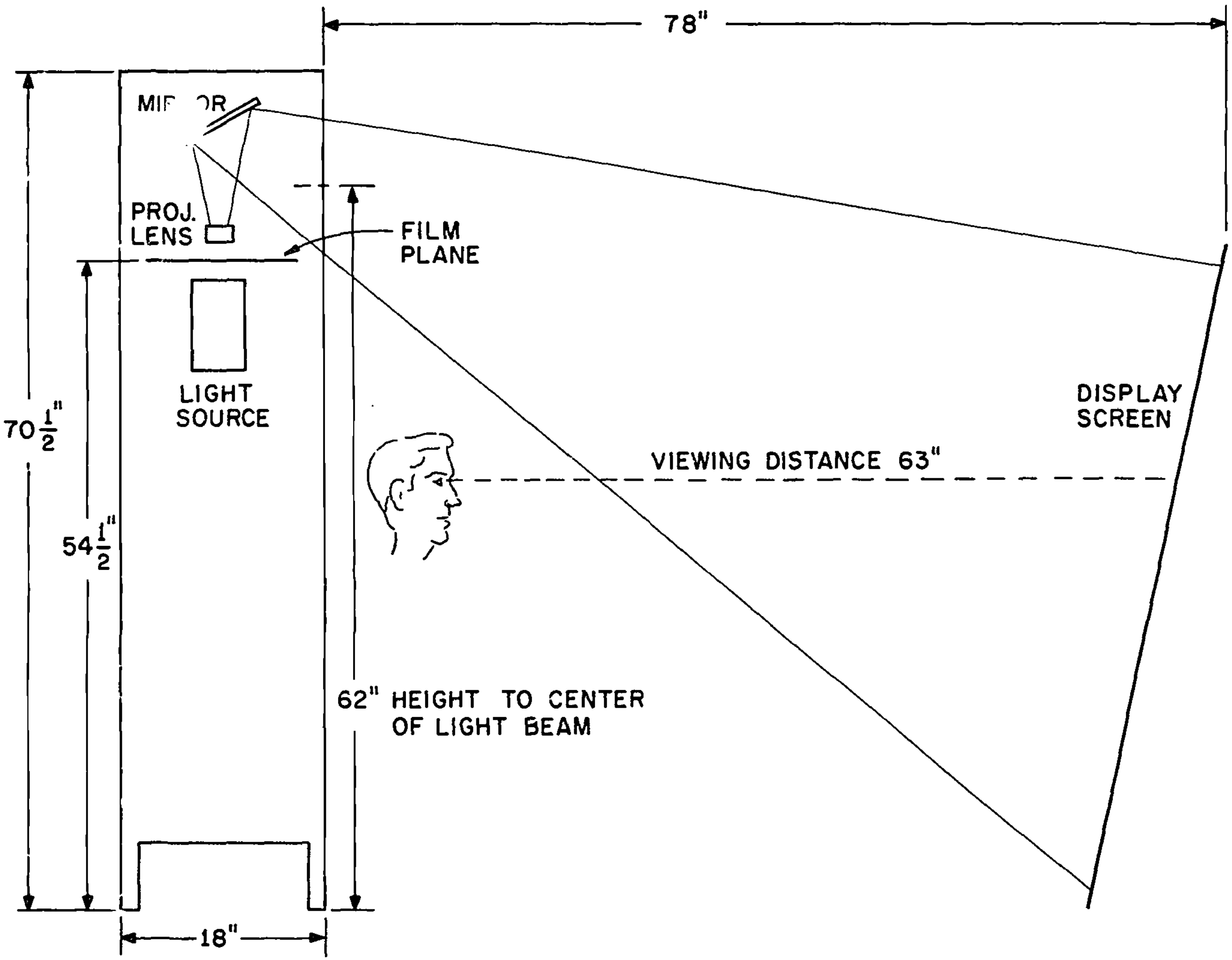


Fig. 2.7 Dimensions of Vertical-Screen Viewer

Although there is virtually no limitation of the projection angle attainable by these techniques, further analysis showed that component requirements become rapidly unattainable for larger projection angles. In order to realistically evaluate the advantages that such a system might offer over the simpler techniques used in the vertical screen and desktop viewers, further analysis and finally a complicated lens-design exercise exceeding the scope of this project would be necessary.

CHAPTER III

FILM TRANSPORT AND CONTROL SYSTEMS

A. INTRODUCTION

The transport system is the part of the viewer that moves the microfilm so that the selected images can be displayed. Particular emphasis in this project was placed on the functional convenience of transport systems, specifically the control portion of the transport system which defines the tasks of the human operator. The decision was made to equip the vertical-screen viewer with a powered transport having remote controls, since presumably the operator could then enjoy the freedom to move about and position himself comfortably, free from the need to be near stationary controls. The desktop viewer is equipped with a manually powered transport system with stationary controls, since the operator is seated at a desk close to the viewer.

Two types of control modes were considered for transport systems for the vertical-screen viewer, namely, velocity control and position control. Velocity control allows the operator the choice of speed and direction, with location-status information used by the operator to guide his decisions. Position control allows the operator choice of endpoint locations; the precise route, speed and other details of travel are outside the control and awareness of the operator.

This chapter discusses the dynamics, human factors and cost factors of these two control modes. Other important characteristics of transport systems including focus control, auxiliary notation systems and shutters or blanking devices are also discussed.

B. VELOCITY CONTROL

The simplest form of velocity control allows for a choice of direction at constant speed along the two microfiche axes. The next level of complexity allows continuous variation of speed via proportional controls. Another variation would be for automatic pause on frame, wherein the transport stops momentarily at each frame. In all cases, velocity controlled transport systems require that the operator is presented with a display of location status. Location status is of two forms: location with respect to internal page numbers, that is, the page numbers that are part of the displayed text in the image, or, the relative location referenced to the microfiche. In normal reading, the text often refers the reader to other pages, and the presence of the page numbers are absolutely necessary to guide the reader and indeed they are always present. The additional information of frame location on the microfiche would presumably allow the operator to choose the most efficient route in accessing remote frames, since microfiche have a two dimensional array of images and there is no unique route between remote frames. A display of frame location, however, poses problems of additional mechanical complexity and presents the possibility of complicating the cues to the operator.

C. POSITION CONTROL

The two position-control schemes considered differed only in the user-manipulated hardware. The first scheme consists of 61 buttons, one for each of the 60 frame locations on the microfiche and an additional load position button. The second scheme consists of 18 buttons, one for each of the five rows and 12 columns on the microfiche and a load position button. The 60-button matrix requires the operator to push only one button and also allows the operator to visualize various locations on the microfiche. The row and column arrangement requires the operator to select a row and column button, but significantly conserves expensive hardware. Either of these button arrangements can display frame location by requiring the buttons to be of the interlocking and latching type, or equipped with internal lights to indicate current location.

D. COMPARISON OF VELOCITY AND POSITION CONTROL SYSTEMS

There are few differences between the mechanical devices required for velocity and position control of a microfiche viewer. Either system requires a carriage to which the microfiche is clamped while it is being moved, as well as motors, gears, and belts (or other means of obtaining linear motion from shaft rotation) to drive the carriage. The requirement of a platen or other device to assure focus of the projected image is also common to both systems. The only differences are in the controls which the operator actuates to move the microfiche and in the means used to indicate which microfiche image is being examined.

The control station of a velocity control system needs only a device to produce motion of the microfiche in either direction in each of the two axes. In its simplest form, only one speed is available in each axis and the control station can consist of four pushbuttons. A somewhat more complicated form provides two, or possibly three, speeds in each axis, one for rapid motion from one microfiche image to another, and slower speeds for accurate positioning of the projected image on the screen. For this form, a push button for each added speed could supplement the basic four push buttons. The use of a joy stick or comparable actuating device for proportional control (i.e., the direction and amount of control motion determines the direction and speed of microfiche motion) adds significant mechanical complication to the control station.

Although an auxiliary device to indicate the position of the microfiche could be made, it is far less expensive to let the user observe the image projected on the screen to determine when the desired position of the microfiche has been reached. Hence, blanking of the screen during microfiche motion is impractical, and microfiche motion must be slow enough to enable the user to know how many images have

been passed and to stop the microfiche at the desired viewing position. The absolute maximum speed, under this restriction, is three images per second, and a more practical speed that results in fewer adjustments to get the image centered and consequently less user frustration — is two images per second.

Position control can be used to move the microfiche from one position to another faster than is possible with velocity control for a number of reasons. First, the position sensing or counting system that must be included in a position control system can react to speeds much faster than the two or three images per second limit of the human operator. Second, the position control system can move the microfiche along both axes simultaneously without confusion. This is also possible with a velocity control if the operator has had extensive training, but the average operator will move the microfiche first along one axis and then along the other. Third, the operator selects the microfiche image which he wishes to read, and if the images are placed as they should be on the microfiche, the position control moves the microfiche to the exact position required to project that image without the subsequent fine position adjustment that might be required with velocity control. It should be mentioned that little is gained by decreasing the time required to change images much below 0.4 sec or so because this is the time required by the user to recognize the new image.

The cost of implementing a microfiche reader with position control must be somewhat higher than the cost of a reader using velocity control because the position control system must use a more elaborate control station as well as a position counting or feedback device, not required on the velocity system, to indicate when the microfiche has reached the desired system. The actual difference between the costs of the two systems, as well as the total cost of either system, is very much dependent upon the particular implementation considered.

The systems constructed under this grant can serve as an example. It is estimated that the combined cost of the carriage, drive motors, and electronics of the position control would be approximately \$200 higher than the corresponding counterparts of the velocity control system, provided the units were made in reasonable quantities and development costs are not included. The control box for the position control system, with its elaborate interlocking, illuminated push button matrix would cost approximately \$275 more that the simple control box of the velocity control system. Thus, the difference in cost would be approximately \$475. The difference can be reduced to approximately \$225 if one push button is used for each row and column (17 push buttons total) instead of one push button for each microfiche image (60 push buttons total).

It is doubted that an implementation that reduces the cost differential of the two systems much below $150 is possible because the additional requirements of the position control system will always result in additional cost.

Thus the trade-offs between position control and velocity control are the time saving and convenience of the position control weighed against the lower cost and possible relative simplicity of velocity control. A choice between the two systems should be made on this basis. The use of a proportional velocity control that incorporates a proportional control probably negates any advantage of cost or simplicity associated with velocity control.

E. UNIFORM AND CONSTANT FOCUS

Another important aspect of the transport system is the ability to produce uniform focus for the entire field of view and maintain focus for all locations on the microfiche. Using as a standard a 0.01 in. diameter circle of confusion at a 10 in. viewing distance, the depth of focus for the desktop viewer is ±0.006 in. and for the vertical-screen viewer is ±0.003 in. Since microfiche are required to be flat to ±0.125 in., the need to clamp or flatten the microfiche is obvious.* Clamping can be achieved either by placing the entire fiche between glass flats, or clamping only the portion of the microfiche in the film gate with a smaller glass flat or platen. Since the entire swept area of the larger glass flats is approximately twice the fiche dimension, or 8 in. x 12 in., it is difficult to maintain the required tolerances for constant focus unless the glass flats are clamped against a reference surface. With a glass platen, the referencing for constant focus is achieved when the spring-mounted floating-glass platen bears against the portion of the microfiche in the film gate and forces it against a reference glass flat. Focus over the entire field area is achieved simply by initial alignment of the reference glass flat.

Since a platen can be placed so that the user will not normally smudge it with his fingers during loading of the microfiche, it seemed to offer an easier method of keeping the optics clean than would be available with the larger glass. This method was used for both the desktop and vertical-screen viewers. However, since the reference glass remains stationary, some provision for releasing the platen during film motion is necessary to prevent wear and scratching of the platen glass, reference glass and microfiche.

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* USASI standards require that curl and bow of microfiche not exceed 0.25 in. maximum.

F. AUXILIARIES

A small memory or notation system can be useful in cross-referencing with a position-control transport. This memory system would be used to mark the location of a few frames corresponding to pages which are referenced most frequently on a particular fiche, for example, the table of contents or a graph or diagram. One simple method for implementing this capability would be with "marker" lights to identify various frame locations. These lights could be either a separate bank of lights in a matrix array corresponding to frame locations on the fiche or located within the buttons of the position-control user's station. In order that the light associated with a particular frame location remain activated, a separate control is necessary. One mode of operation is as follows:

1. Suppose the operator wants to note the present frame location for quick future reference. To accomplish this he activates a button which turns on the light in the depressed position button.

2. When another position button is actuated, the light in the original switch remains on.

3. All marker lights are erased with a bulk erase control.

Although this scheme is conceptually simple, some effort would be necessary to provide the same capability at a minimum or practical cost. Furthermore, this notation system would typically be useful for marking only a small number of frame locations, since if more than four or five markers are needed, the operator might find it more convenient to jot down frame locations and the description of the contents instead.

It is interesting to note in passing that should microfiche viewers be standardized to include a specific form of location-status display (as for example, the viewers equipped with a pantograph-type transport), original material could be prepared for microfiche so that internal page numbers coincide with frame location numbers. All the ambiguities and inconveniences of cross referencing within a microfiche would be thus eliminated, and the inherent advantage of reduced page-access time of the microfiche matrix array of pages could be fully realized.

Another auxiliary feature recommended in a position-control transport system is a blanking or screening device to interrupt the image display while the microfiche is in transit. This step is taken to avoid the unpleasant sensation of vertigo or dizziness that may occur when images are viewed as they move across the screen rapidly.

CHAPTER IV

DESKTOP VIEWER

A. INTRODUCTION

The desktop viewer was designed to view the 35-mm filmstrip output of the Project Intrex full-text film terminal. This choice of microform was made so that the desktop viewer could be included in the Project Intrex installation at the M.I.T. Material Science and Engineering Center, an ideal experimental environment in which to present and evaluate a new viewer concept. The 35-mm filmstrip furnished to the user is mounted in two rows with a maximum of seven images for each row in a transparent jacket. The dimensions of this jacket are 3 1/2 in. by 7 3/8 in. which suggests that the basic design of the viewer could easily be modified to accommodate 4 in. by 6 in. microfiche.

Since the desktop viewer was intended for use and evaluation in a working experimental-library environment, much attention was given to packaging and human factors. The decision was made early in the design phase to drop from consideration viewer concepts and geometries inherently incapable of being appealingly packaged and "human engineered", since these aspects have a significant influence on overall user acceptance of a microfilm viewer. In order to further insure the practicality of the final design, no concepts inherently requiring exotic and expensive hardware or methods were used.

B. DEVICE GEOMETRY

A large portion of the design effort for the desktop viewer was concerned with integrating the optical and mechanical systems into an appealing package. Device dimensions were minimized to make the viewer as similar as possible to a journal or book lit by a desk lamp. The basic architecture of the viewer is shown in section view (Fig. 4-1). The transport system is located under the plane of the reading surface since this scheme requires minimal volume and the transport controls are comfortably accessible without complicated mechanical linkages. The location of the transport also allows for easy loading and unloading of the microfilm jackets. The optical path is folded, which minimizes overall height and requires that only the lightweight mirror assembly be vertically supported.

Mockup models were used to determine that a mirror height of 24 in. above the table height, with the mirror located approximately one foot back and away from the desk edge, placed the mirror in a unobtrusive location comfortably removed from the observer's field of view. This mirror position is achieved by using a 105 mm EL-Nikor lens as the projection lens with a 23.5 deg projection angle. The 23.5 deg projection angle is achieved by locating the film gate 13 deg

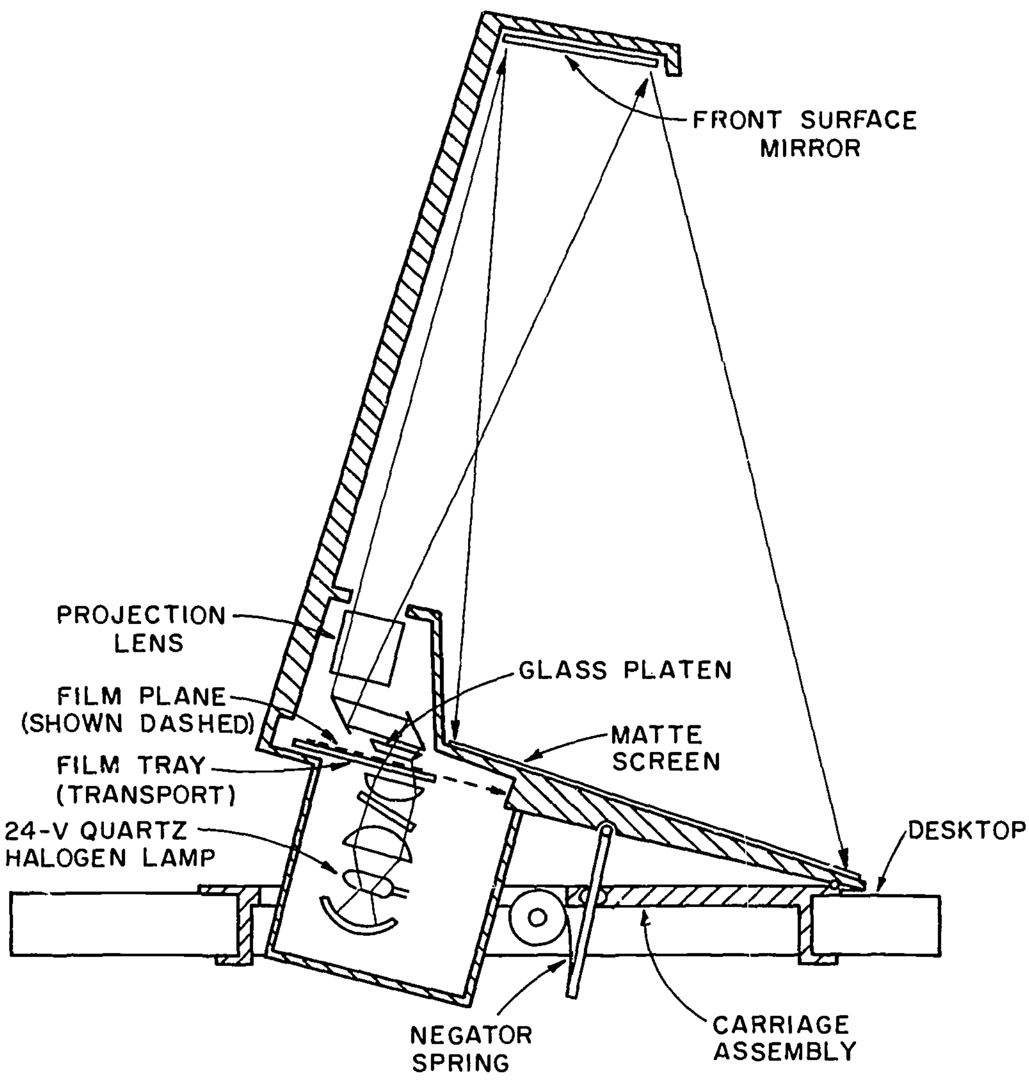


Fig. 4.1 Section View of Desktop Viewer

off the lens axis and tilting the conjugate object and image planes 1.1 deg and 10.5 deg respectively. The images on the 35-mm strip film are a 10X reduction and the transverse magnification of the desktop viewer is exactly 10X at the image center. However, the transverse magnification varies from 9.8X at the top, referenced to the user's view, of the image to 10.25X at the bottom. Also, the vertical magnification tends to be somewhat larger than the horizontal or transverse magnification and is 10.3X at the top, 10.7X at the center and 11.2X at the bottom. The 23.5 deg projection angle is a compromise of image resolution and distortion on the one hand, and user light-ray interference and unobtrusive mirror position on the other hand.

C. THE OPTICS

The collector optics, including the condenser lenses, spherical mirror behind the lamp and infrared filter are mounted in a subassembly available as a standard part of the Prado Universal Projector manufactured by E. Leitz, Inc. Other parts of the Prado also used were: lamp, lamp base and lamp centration device and 24-v transformer. The Osram 64655 24-v 250 watt quartz halogen lamp is cooled indirectly by a 60 cu ft/min capacity Rotron "Whisper Fan" mounted on the side of the lamp housing. Although no specific effort was made to provide additional air cooling to the film or the clamping platen glass, no film overheating has been observed. The 24-v transformer that supplies lamp current is bulky and heavy and is remotely mounted under the desktop.

The lamp and collector system together with the f/5.6 projection lens yields 210 footlamberts screen brightness for an 85 percent reflecting diffuse screen at the nominal 10X magnification. The contrast performance of the desktop viewer is presented in Fig. 2.3 and is considered to be quite satisfactory. A 20X magnification system for microfiche would require an f/2.8 projection lens to exhibit similar contrast, but the increased aperture is easily attainable with the shorter focal-length lenses necessary for 20X magnification at the same projection or throw distance.

Image brightness is attenuated through the use of reduced reflectivity screens. Since commercially available matte screens have reflectivities of 75 percent to 85 percent, special screens were fabricated by painting 1/16 in. thick phenolic sheets with flat Latex white paint tinted with a black pigment. Screens with reflectivities vary from 0.3 to 0.7 were prepared and can easily and quickly be interchanged by the user to achieve the image brightness he desires. The screen with reflectivity of 0.5 is the most preferred for ambient illuminations in the range of 40 to 80 footcandles. Screen dimensions are 9 in. by 11 1/2 in.

The 35-mm strips from the Project Intrex full-text facility are the result of 2000 lines-per-frame electronic scanning and have a

limiting resolution of approximately 28 line pairs/mm. Since the projection lens has an average resolution of 180 line pairs/mm for the 13 deg off-axis film gate, the limiting image resolution is largely determined by the filmstrip. The final image resolution of the filmstrip, projection lens and matte screen is approximately 2.3 line pairs/mm. With higher quality 35-mm filmstrip, 100 line pairs/mm for example, resolutions on the order of 6 line pairs/mm should be possible.

D. TRANSPORT AND CARRIAGE

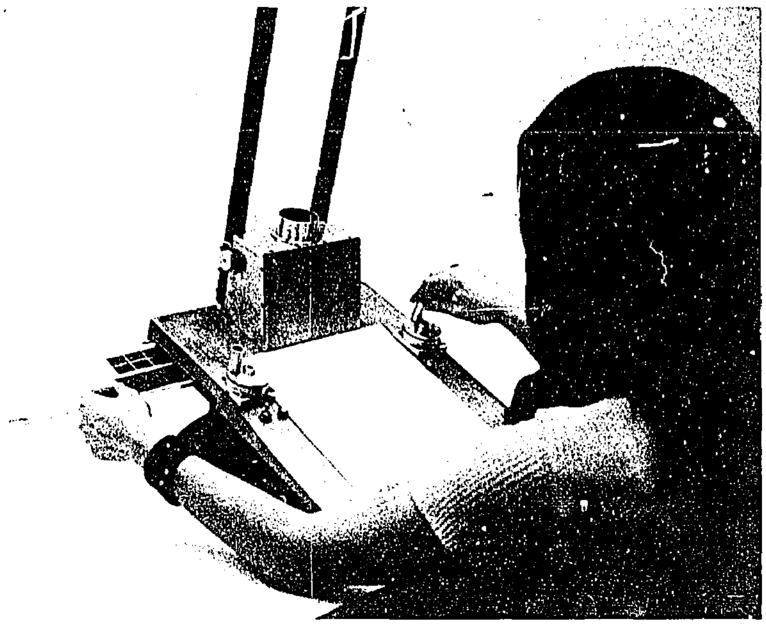
The transport for the desktop viewer is a manually operated system characterized by the ease and convenience of loading the jacketed 35-mm film. The film jacket is loaded into the transport tray (see Fig. 4.2) in a manner similar to loading paper into a typewriter carriage. The jacket is inserted into the tray until resistance is felt, thus indicating that the jacket is bearing against the friction rollers. The operator then engages the horizontal control which rotates the friction rollers; the film jacket is then engaged in the transport system. Since the tray must also move along the orthogonal axis so that both the upper and lower film strips may be displayed, the friction rollers are mounted on shafts which are rectangular in cross section at one end. This flattened portion moves through a slotted pulley which is linked to the control crank by a belt. In this way, the horizontal control crank provides torque to the friction rollers regardless of vertical tray position. Vertical tray motion is achieved by a belt fixed directly to the tray. This belt is driven by a pulley linked to the vertical control crank.

The ease of loading the jacketed film results from the fact that there is no specific load position, that is, the tray can be loaded in any position along its vertical travel and the symmetry of the transport tray allows loading and unloading from either side of the viewer. Further, a film jacket can be loaded without unloading the previous film jacket since as the jacket loads, the previously loaded jacket unloads simultaneously. This situation is ideal for quick scanning of several film jackets where ordinarily the loading and unloading procedure could become tedious.

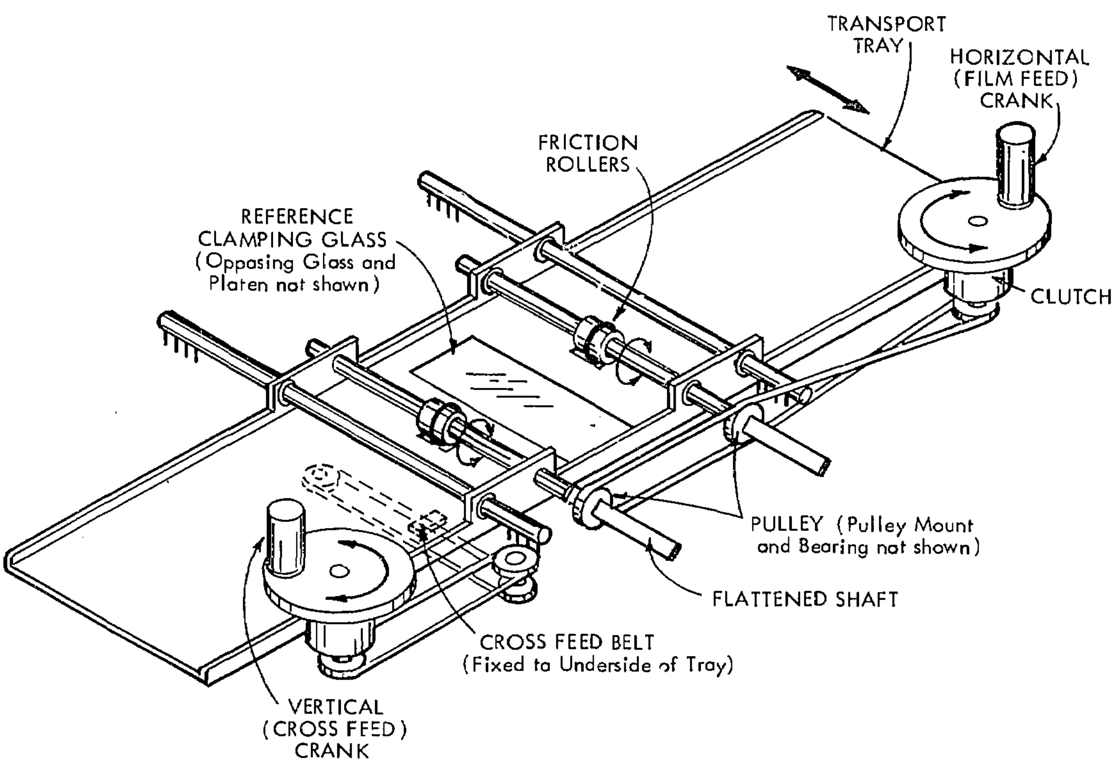
The jacketed film is kept flat at the film gate by means of a platen. The platen is disengaged during film motion by the following interlocking system.

1. The platen is raised and lowered by a solenoid. The energizing solenoid current is gated by a microswitch which is activated by depressing the vertical or horizontal control crank.

2. When the solenoid is engaged, the contacts close, gating the current which energizes the drive clutches.



(a) LOADING FILM JACKET INTO VIEWER



(b) ARRANGEMENT OF PARTS

Fig. 4.2 Desktop Viewer Transport System

Therefore, the operator must depress the control cranks in order to engage the drive mechanisms, in which case the platen is automatically raised before film motion occurs. If the operator does not depress the crank, but just rotates the crank, nothing happens. The cranks are depressed approximately 1/16 in. with a 1/2-lb force. The ratio of 1.8 in. horizontal film travel per 360 deg of crank rotation allows for rapid film advance and accurate centering of the image.

The entire desktop viewer is mounted to a carriage which allows the user to rotate the reader on the desk surface and tilt the entire viewer so that the display screen can be positioned for maximum comfort (see Figs. 4.3 and 4.4). The carriage is primarily a rotating baseplate to which the viewer is attached by means of a hinge located along the forward edge. The center of the baseplate is removed to provide clearance for the lamp housing, and thus permits the viewer to lie flat. Since the torque required to tilt viewer about the hinge is considerable, negator-type strip springs were provided. The resulting force necessary to tilt the viewer by grasping the mirror support rods is on the order of a few pounds. A positive lock prevents gradual change of the tilt position that might result from the force necessary to depress the control cranks during usage. Rotation of the entire assembly is accomplished by grasping any convenient part of the viewer and applying force in the appropriate direction. The center of rotation is located approximately three inches from the center of the screen to allow for comfortable positioning of the display screen during note-taking. The bearing surface on which rotation occurs provides sufficient friction to prevent carriage rotation during crank depression or accidental bumping, but the force required to rotate the carriage is small.

E. EVALUATION AND SUGGESTIONS

Because of delays in the installation of the Project Intrex facilities at the M.I.T. Materials Science and Engineering Center, the desktop viewer has not been fully tested in a working-library environment. On the basis of the limited exposure to users thus far, it is likely that the viewer will be very well received by a general usership. The features that receive the most favorable comments are the image quality and the nondirectional matte screen. Many favorable comments have also been made on the ability of the unit to be rotated and tilted, to maintain focus uniformly and constantly, and the ease of loading and unloading.

In the limited usage so far, it seems as though the tilting feature is appreciated by users when it is demonstrated to them, but it is seldom used once the screen plane is adjusted to approximately 15 deg from the horizontal. This suggests that a fixed tilt angle of 15 deg could be used, which would allow sufficient space for the light source and so forth in the volume between the screen plane and desktop.

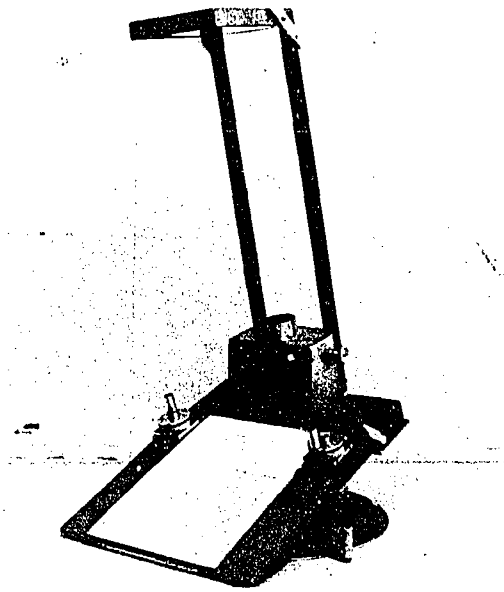


Fig. 4.3 Desktop Viewer Shown Rotated to Right

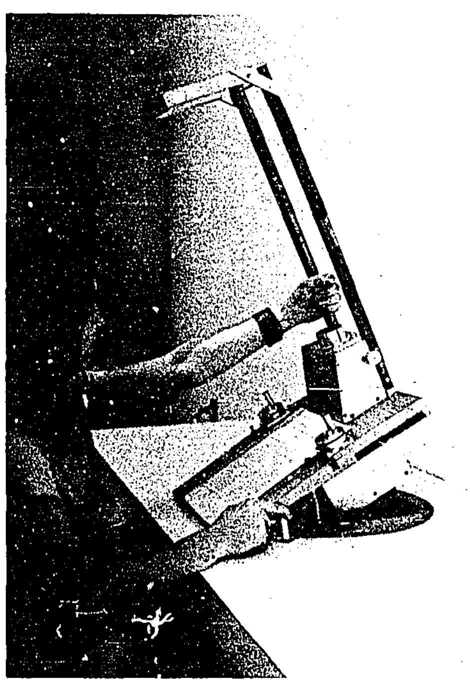


Fig. 4.4 User Shown Changing Tilt Angle

Then, rotation could be easily achieved by a simple baseplate and bearing upon which the viewer would rest. In this way, the baseplate could be reduced and greatly simplified, and most importantly the entire viewer becomes easily transportable from desk to desk.

Reliability of the unit has been excellent. No important mechanical failures have occurred and none are anticipated.

CHAPTER V

VERTICAL-SCREEN VIEWER

A. INTRODUCTION

The vertical-screen viewer developed as part of the project can be described as a "mini-microfilm theater". It has been designed to view the microimages of COSATI format microfiche. This mini-theater configuration frees the user from the confines of a desktop environment and its associated restrictions of viewing angle and seating position. The large image (4X actual size) and viewing distance of five feet allow the user full freedom of seating position in a comfortable easy chair.

Throughout the design phase, emphasis was placed on practicality and simplicity. The overall device geometry conserves floor space (approximately 25 square feet are required), places the transport near the user for convenient loading and unloading and avoids interference between the user and the projected light rays. The optical system is simple. It uses parts normally found in commercially available slide projectors.

Two alternate transport systems have been provided for the vertical-screen viewer, a velocity-control, stepping-motor drive system and a position-control, continuous-servomotor system. These systems were designed and constructed primarily to test the effectiveness of control modes and other auxiliary features.

The vertical-screen viewer is currently in use and is being evaluated at the M.I.T. Barker Engineering Library (see Fig. 1.2). The enthusiastic user response indicates that this kind of viewing system would be well received on a widespread scale.

B. DEVICE GEOMETRY

In order to conserve floor space and to have the film transport convenient to the user, the decision was made to place the projector portion of the viewer close to the user. All possible projector locations near the user were examined, and it became increasingly evident that the most practical scheme was to place the projector behind the user. A mirror directs the light up and over the user's head to the screen. In this way, the optical path is folded and a projection lens with a modest angular field can be used. Studies were made to determine a comfortable screen height, and to select the projection angle, screen tilt angle and mirror height. The final dimensions are as shown in Fig. 2.7.

The screen tilt angle of approximately 12 deg reduces the projection angle to approximately 12 deg. The 12-deg projection angle

is obtained by tilting the film plane while keeping the film gate centered. In this way, a magnification variation (distortion) of ±3 percent about the image center results. However, since the film gate is centered, optimum use is made of the resolution capability of the projection lens.

C. OPTICAL SYSTEM

The vertical-screen viewer uses the same light source as the desktop viewer, namely, the lamp, reflector, infrared filter and condenser lenses included in the Leitz Prado 35-mm slide projector. In fact, only simple modifications, consisting of removal of the slide and projection lens holders, were made to the Prado projector. The light-source portion which includes cooling fan, 24-v power transformer and optics in their original package is mounted in the vertical-screen-viewer chassis. A good deal of design time was saved through use of this commercially available unit.

The projection lens in the vertical-screen viewer is the 35-mm f/2.8 Elmaron manufactured by E. Leitz. This lens offered the best compromise among cost, resolution at high magnification, short focal length and wide aperture.

The matte-surface screen is a commercially available vinyl-coated fabric. The screen is glued to a plywood surface that is part of a simple easel-like structure.

D. FICHE TRANSPORTS

Two fiche transports for the vertical-screen viewer have been designed and built. These transports have certain hardware in common, but are electrically controlled by different methods and represent two different user-control modes, as discussed in Chapter III, namely, velocity control and position control.

The microfilm-translator stage, consisting of fiche support, column and row carriages, is common to both systems and is shown in Fig. 5.1. The other elements shown in solid lines are also common to both systems, whereas the elements shown as dashed lines are found only in the continuous servomotor drive. Operation of the film translator stage is as follows.

Rotation of the row drive motor moves the positive drive belt attached to the row carriage. The row carriage moves along the two fixed rods, thus moving the bearing, fiche clamp and fiche. The bearing slides along the groove in the column carriage to provide a sliding contact with the column carriage. Rotation of the column drive motor moves a positive-drive belt attached to the column carriage, which drives the carriage along two fixed rods and hence drives the bearing, fiche clamp and fiche. Thus, the bearing, which

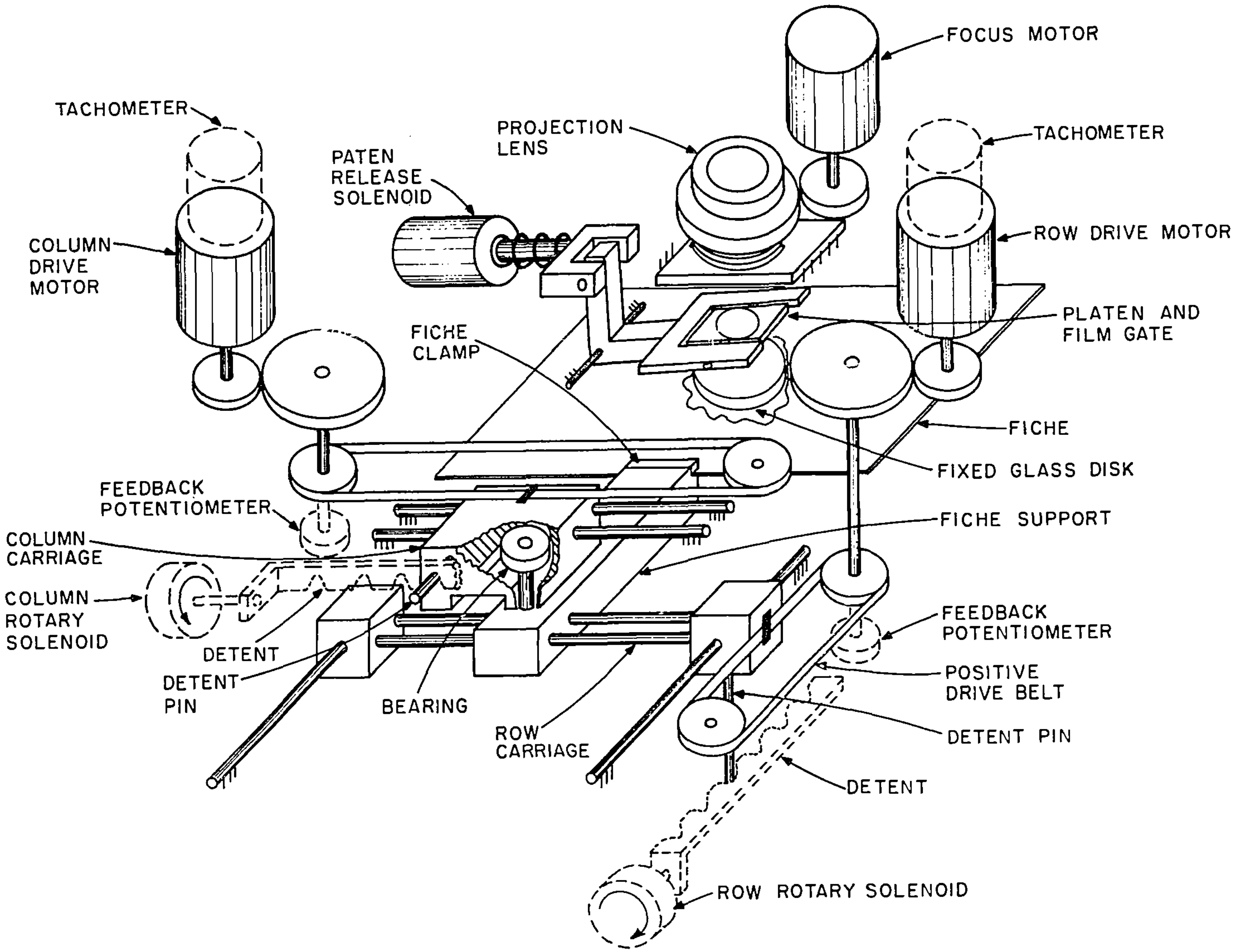


Fig. 5.1 Vertical-Screen Viewer Transport System

provides a sliding contact between the row and column carriages, allows independent travel along row and column axes so that any image on the fiche may be positioned in the film gate.

The projection lens is mounted in a threaded barrel that screws into a threaded fixed plate. Rotation of the threaded barrel causes the barrel and lens to move along the optical axis for focussing. A motor drives the gear mounted on the outside of the threaded barrel. Focussing is performed remotely by the user.

Focus, once set, is maintained for all subsequent frames by a clamping glass platen that positions the frame in the film gate flatly against a fixed reference glass disk. The platen is released during film motion by the platen-release solenoid to prevent jamming and scratching of the fiche and clamping glasses. Features described thus far are common to both transport systems; details specific to each system are now discussed.

E. VELOCITY-CONTROL, STEPPING MOTOR DRIVE SYSTEM

Each stepping motor is driven by a translator which changes the state of its two-phase output so that the stepping motor connected to it advances by a five-degree step whenever a pulse is presented at one of its two inputs. One input is for clockwise rotation and the other for counterclockwise rotation. Each translator contains its own voltage-controlled oscillator to provide the desired pulse rate, and hence any desired stepping-motor rate. The momentary contact push buttons, which are the user-manipulated control hardware, are used to gate the oscillator pulses to either of the translator inputs.

Electrical relays and switches are used in the stepping-motor system to provide the following functions:

- The fiche transport is returned to the position for inserting or removing fiche when the "load" button is depressed and held until the carriage stops moving.
- When the load lever is raised, the clamp that attaches the fiche to the transport is released. The drive system is deactivated so that the transport cannot be moved, and the platen is unclamped so the fiche can be inserted.
- An interlock is provided on the platen solenoid so that the fiche cannot be moved while the platen is clamped. This feature avoids damaging (or jamming) fiche.

- The push buttons on the control box are interlocked so that no damage results from depressing any number of buttons.

The load procedures for the stepping-motor transport system are:

1. Press the "load" push button on the transport and hold it down until the fiche support stops. (Sounds of the stepping motor stop), see Fig. 5.2.

2. Hold loading lever up against stop and insert fiche in loading slot as far as it will go under light pressure. The fiche is now ready for frame positioning.

3. The buttons on the control box (see Fig. 5.3) to the right and left of the center button move the fiche to show images on the same row on the fiche, and the upper and lower push buttons move the fiche to show fiche images in the same column on the fiche. Fine positioning can be obtained by jogging, or the center push button can be depressed simultaneously with any of the four direction buttons to obtain slow motion of the fiche.

4. The two push buttons on the right of the control box in Fig. 5.3 control the focus motor. The appropriate push button should be held down until the focus motor drives the projection lens to the desired focus position.

5. To remove the fiche, depress the "load" button until the fiche support stops moving. Lift the load lever to unclamp the fiche, and gently pull the fiche from the slot.

F. POSITION CONTROL, CONTINUOUS-SERVOMOTOR DRIVE SYSTEM*

Devices which are different in the continuous-servomotor drive from the devices in the stepping motor drive are shown with dashed lines in Fig. 5.1. These differences include tachometers mounted on servomotors, detent pins, detent bars and the rotary solenoids that actuate them, and feedback potentiometers. One other device, not shown in Fig. 5.1, is a shutter that inserts a translucent, diffusing screen in the light path between the platen and the projection lens whenever the fiche is being moved. The object of this shutter is to avoid the usually disturbing effect produced when images are moved rapidly across the screen.

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* This section is based upon the work of Professor H. H. Richardson, Professor D. N. Wormley and Mr. Daniel Jacob, Research Assistant, M.I.T. Mechanical Engineering Department.

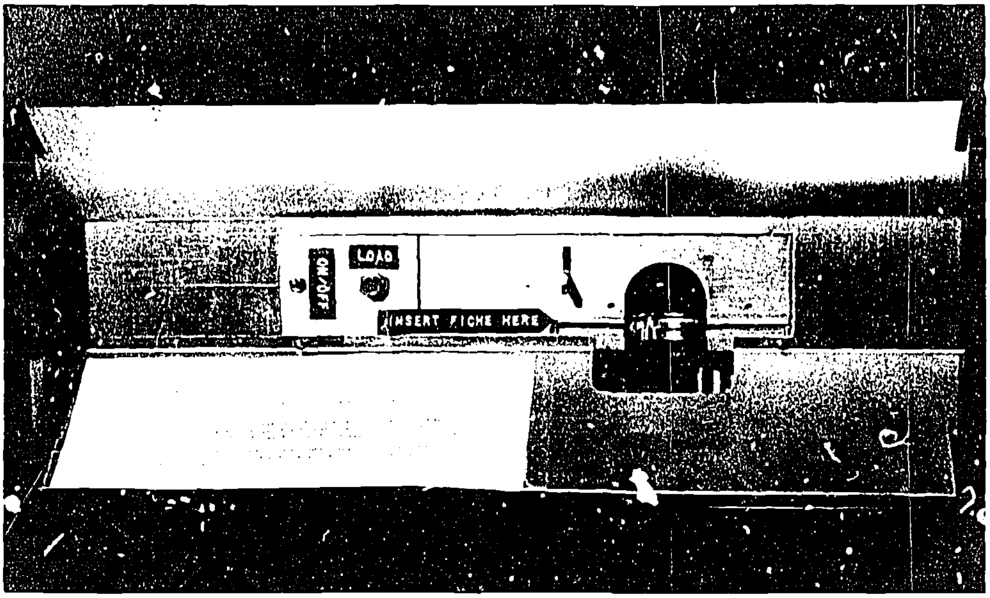

Fig. 5.2 Power Switch and Loading Controls of Velocity-Control Microfiche Transport

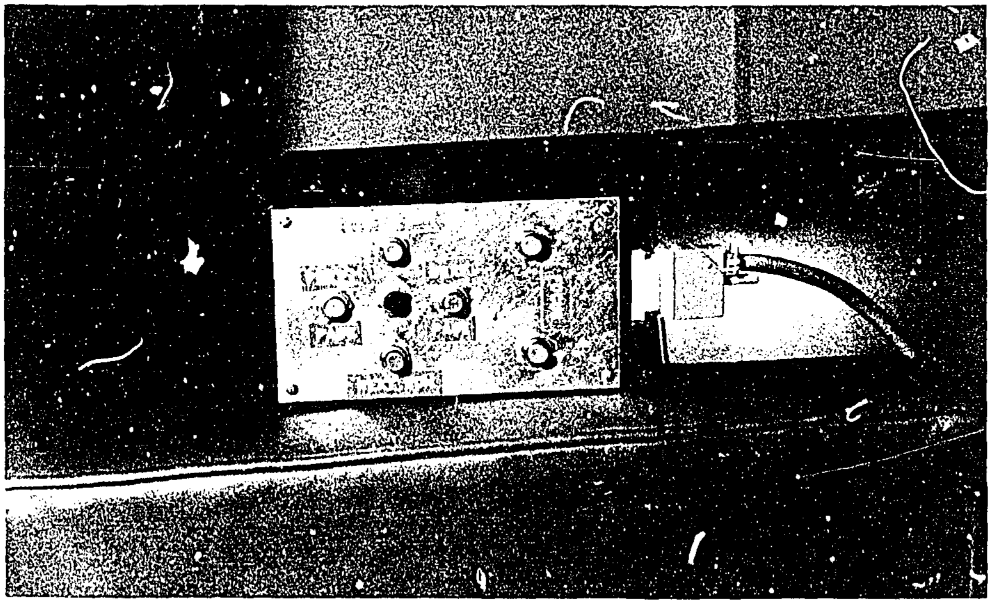

Fig. 5.3 Control Box for Velocity-Control Microfiche Transport

The drives of the continuous-servomotor system consist of two true continuous-position servomechanisms that have their outputs locked at predetermined positions if the errors fall below prespecified levels at any of these positions. Each of these two servomechanisms, one for the row drive and one for the column drive, uses tachometer feedback to produce an almost critically damped servomechanism. The feedback potentiometer on each drive is the output-position transducer for the drive servomechanism.

A schematic diagram of a carriage drive servomechanism is shown in Fig. 5.4. Depressing a push button in the command matrix closes one of the switches to a potentiometer wiper shown toward the left of the figure. The switches are interlocked so that only one can be closed at a time, and once closed, the switch remains closed until another switch is closed. The voltage between this switch and the feedback-potentiometer wiper is the position-error voltage which is applied to the input of linear amplifier A_1 through a mixing network to drive the servomotor, and hence the carriage.

Voltage from the tachometer generator driven by the servomotor is also applied to the mixing network to damp the servomechanism. Amplifier A_2 is a high-gain, saturating amplifier whose function is to apply a signal to the mixing network such that the resulting output of amplifier A_1 is almost sufficient to overcome the friction of the transport carriage. This feed-forward, load-torque-compensating path will produce instability if the gain of the loop is too high, and hence must be carefully adjusted with the potentiometer at the output of amplifier A_2.

As was stated above, the output of each servomechanism drive is locked at prespecified positions if the error has fallen to a predetermined level when the output position is at one of these positions. The detents and detent pins shown in Fig. 5.1 accomplish this locking function. As shown in Fig. 5.1, both drives are locked. When either servomechanism position error exceeds a prespecified level, current is passed through the corresponding rotary solenoid, causing it to rotate in the direction indicated by the arrow to release the carriage. The carriage would then move to reduce the error until it falls to the prespecified level, and the solenoid is de-energized. The detent slots are tapered so that if the detent pin does not originally lie at the slot center, the spring that returns the solenoid to its unenergized position also forces the detent pin to the bottom of the slot, and hence brings the carriage to a predetermined position.

The circuit used to actuate each rotary solenoid is shown in Fig. 5.5. The a-c position error of the drive servomechanism (the position-error voltage of Fig. 5.4) is rectified and compared with the magnitude of a rectified reference voltage. When the error voltage is greater than the reference voltage, the amplifier output voltage is positive, causing the transistor to conduct, and current flows in the

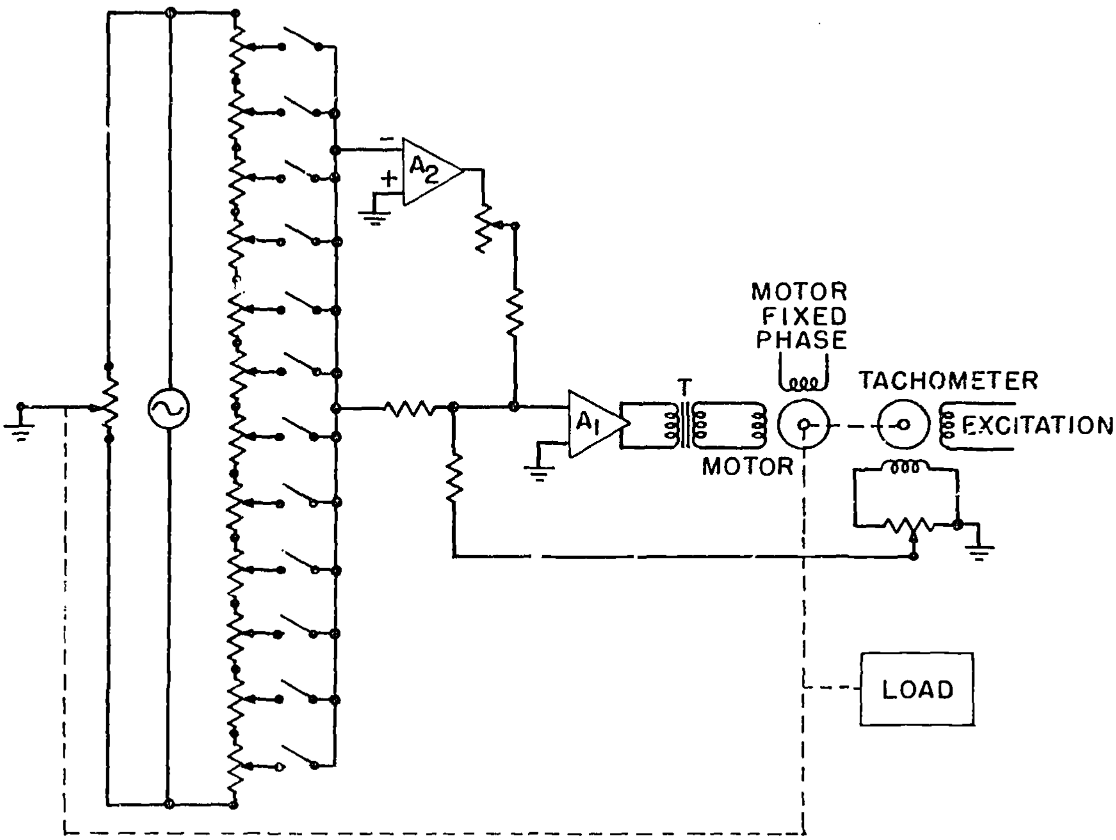

Fig. 5.4 Servomechanism Schematic

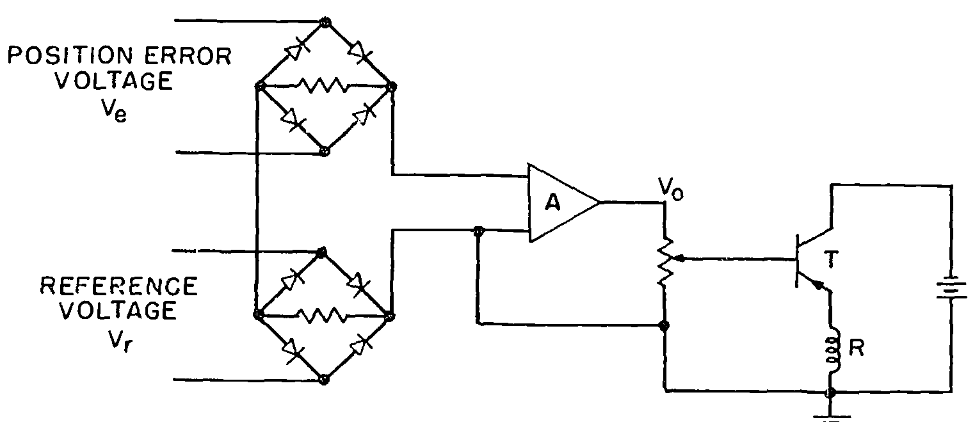

Fig. 5.5 Error Amplifier for Detent

solenoid coil, thereby releasing the detent. When the error voltage is lower than the reference voltage, the amplifier output voltage will be negative, the transistor will be cut off, current will not flow through the solenoid coil, and the detent slot will engage the detent pin.

The use of detents in this transport makes it impossible to scan (inch) the image so that it is centered in the film gate. The portion of the fiche that is projected on the screen depends entirely upon how the fiche is clamped in its holder, and how the images are arranged on the fiche. This has the disadvantage that the film gate must be made large enough to accommodate an image placed anywhere within the location tolerance, and hence there will usually be a bright region somewhere adjacent to the projected image of a negative fiche.

A number of electrical interlocks are provided in the continuous servomechanism transport. When the detent of a carriage drive engages the detent pin, power is removed from the reference field of that particular servomotor to prevent excessive motor heating and to avoid the torque and noise that would result from amplifier noise voltage applied to the two-phase motor if the reference field were left on. Also, when either detent is not engaged with its detent pin, an electrical interlock prevents the film gate platen from engaging, thus leaving the fiche free to move. The single exception to this interlock occurs when the carriage drives are in the "load" position. In this position the platen is released when the load switch is in the "load" position. When the load switch is placed in "operate" position, the platen clamps the fiche even if it is in the "load" position. Finally the solenoid which unclamps the fiche from the fiche support can be energized only when both carriage drive are in their "load" position.

The steps required to use the continuous servomotor drive system are:

1. To load a fiche into the reader or to remove a fiche, place the load-operate switch in the "load" position (see Fig. 5.6). This causes the carriage to move to the load position, the platen to release, and the fiche clamp solenoid to release the clamp. The fiche can then be either inserted or removed.

2. Move the load-operate switch to the operate position. This causes the fiche to be clamped to the fiche support and the platen to clamp the fiche when the fiche is not being moved.

3. Depress the push button on the push button matrix to project the desired fiche image, (see Fig. 5.7).

Further details and a complete discussion of the Position Control Continuous Servomotor Drive System can be found in an M.I.T. Master's Thesis by D. Jacob (see Ref. 4).

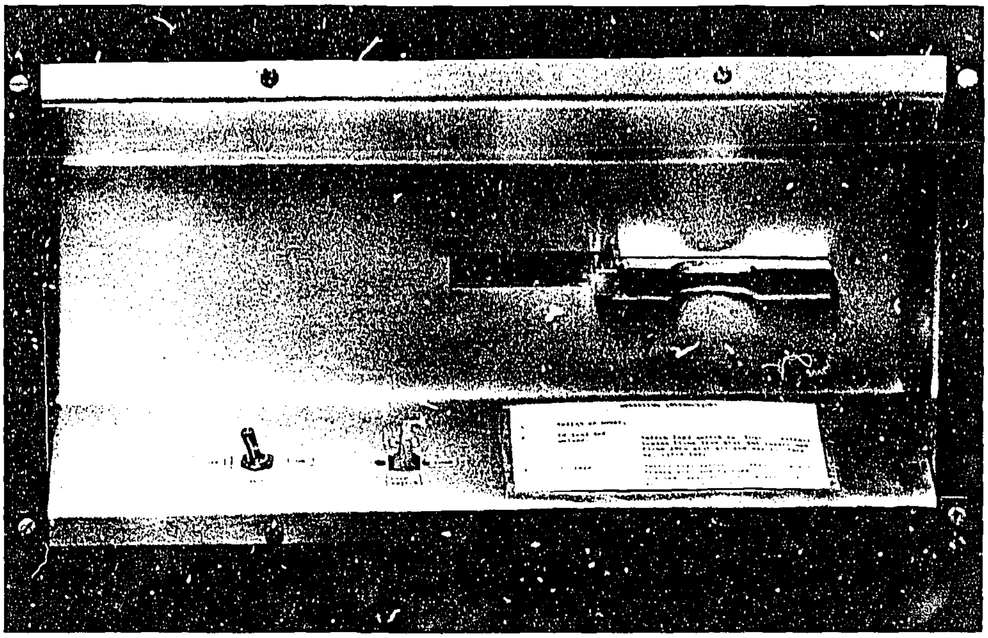

Fig. 5.6 Power Switch and Loading Controls of Position-Control Microfiche Transport

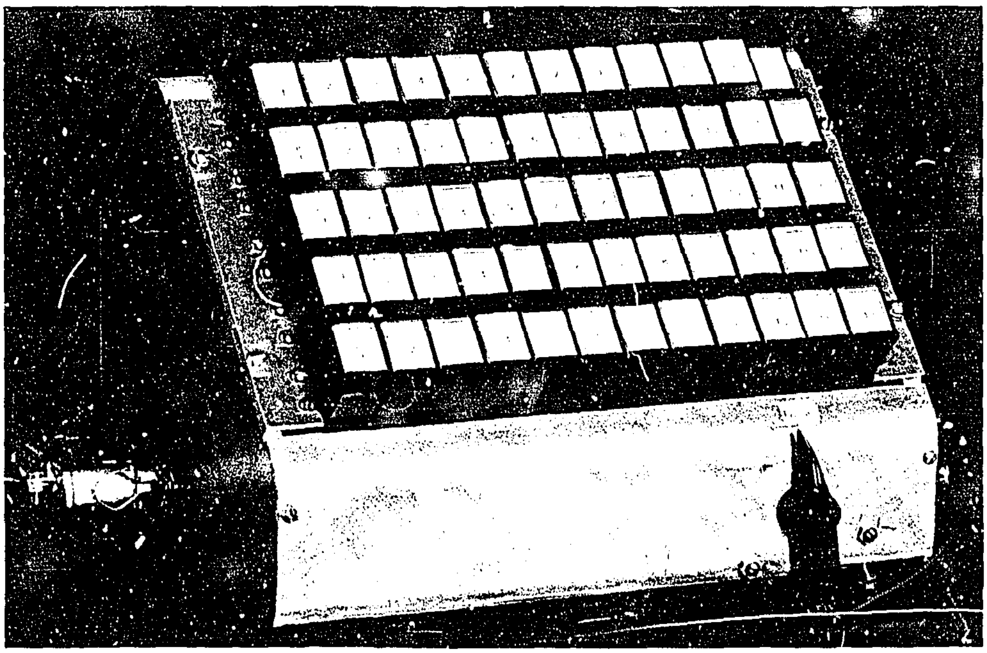

Fig. 5.7 Control Station for Position-Control Microfiche Transport

G. POSITION CONTROL, STEPPING MOTOR DRIVE

Logic was designed which would project the fiche image of a particular row and column. The control station would be equipped with five (or six) row push buttons and 12 column buttons. When one row and one column push button is depressed, the carriage moves to project the corresponding image. Inching buttons — right, left, up, and down — would be supplied to permit fine adjustment. A schematic diagram indicating the decisions and required interactions of the control system is shown in Fig. 5.8. In this figure, one control motion (the column drive) is shown. A similar system would be required for the other drive. In this system, the column order push button (top center in diagram) inserts the ordered column into the comparator as a binary number. This is compared with the output of the column counter, and if the two numbers are not the same, pulses pass through the switch to the steering network, and then to the translator, which steps the motor a fixed angle for each pulse received. The same pulses are counted in the pulse counter; the counter resets itself and passes a pulse to the column counter each time the number of pulses are transmitted to the stepping motor are enough to cause it to move the carriage the width of one column. When the column comparator indicates that the ordered and projected fiche columns are the same, the switch between the pulse source and the counter opens, and the stepping motor stops. Inching can be obtained by depressing one of the manual buttons to permit pulses at reduced frequency to pass to the stepping motor. Not shown in the diagram are the interlocks necessary to deactivate the manual system if both buttons are depressed simultaneously. Also not shown is the counter that must limit the number of pulses that can be introduced by the manual system to prevent complete loss of meaning of the column order push button numbers.

The paper design of control system is complete, but has not been implemented.

H. EVALUATION

The vertical-screen viewing system is installed at the M.I.T. Barker Engineering Library and evaluation studies of it have been made. Persons making requests for copies of microfiche at the Microform Service Area desk were encouraged to use the experimental vertical-screen viewer. The persons who did use it were asked to fill out a brief questionnaire. This questionnaire is reproduced in Fig. 5.9, with the percentage distribution of the responses of 60 users shown in the answer spaces. Forty of the users operated the system with the velocity control transport system installed, and their responses to question number 6 are shown enclosed in a rectangle in Fig. 5.9. Twenty users operated the system with the position control transport system installed and their responses to question number 6 are shown in an ellipse.

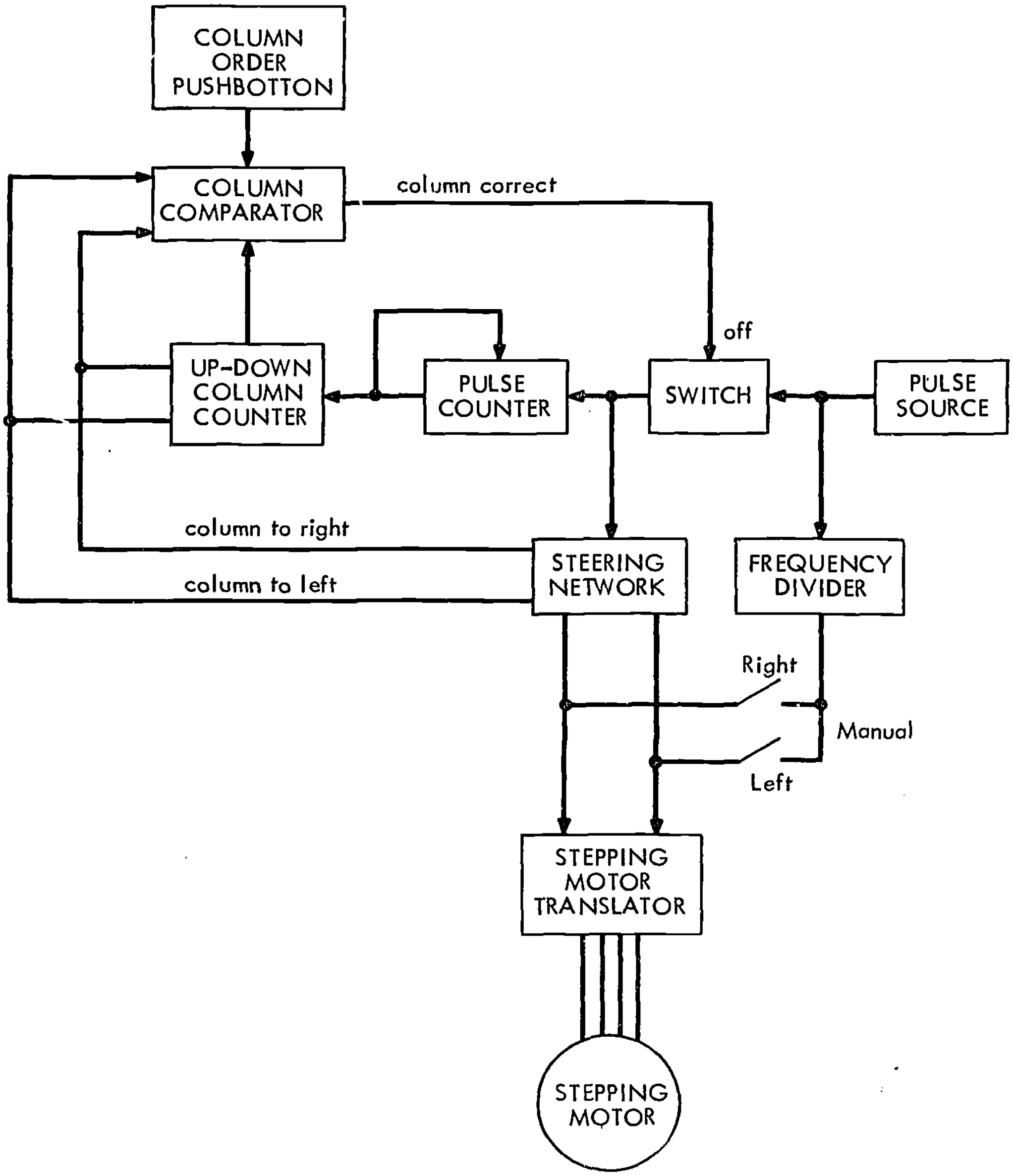

Fig. 5.8 Schematic Diagram of One Control Axis of Row-Column Stepping-Motor Drive Microfiche Transport

QUESTIONNAIRE - EXPERIMENTAL MICROFICHE READER

1. About how many minutes did you view the reader? 29 average (See text)

2. When using this reader, was your sitting position more or less comfortable than your sitting position at standard microfiche readers?

   more comfortable 85 % less comfortable 5 % about the same 10 %

3. What are your feelings about sitting at a distance from a large screen (as with this reader) rather than sitting close to a small screen (as with standard microfiche readers)?

   75 % I like sitting at a distance from a large screen.

   14 % I like sitting close to a small screen.

   11 % There isn't much difference.

4. How did you find -

   a. Image sharpness: Good 63 %, Fair 33 %, Poor 4 %

   b. Image-to-background contrast: Good 74 %, Fair 26 %, Poor -

   c. Image brightness: Too bright 4 %, Too dim 5 %, OK 91 %

   d. Image size: Too big 5 %, Too small 7 %, OK 88 %

   e. Screen height: Too low 21 %, Too high 4 %, OK 75 %

5. Did you notice significant image distortion?

   Yes 8 % No 92 %

6. Compared with the manual positioning controls on the other microfiche readers, did the automated position controls of this reader make it easier or harder to find a page?

   Easier to find a page $\boxed{39\%}$ (88 %) Harder to find a page $\boxed{45\%}$ (-) About the same $\boxed{16\%}$ (12 %)

7. Compared to translucent rear projection screens typical of standard microfiche readers, was this screen easier or harder on the eyes?

   Easier on the eyes 71 % Harder on the eyes 13 % No difference 16 %

8. Other comments:

[ ] = responses with velocity-control transport

( ) = responses with position-control transport

Fig. 5.9 Questionnaire for Evaluation of Vertical-Screen Viewer

User operating time varied from five minutes to three hours and averaged 29 minutes. The frequency distribution of operating time is as follows: less than 15 minutes: 43 percent, 16 to 30 minutes: 28 percent, 31 to 60 minutes: 10 percent and over one hour: 19 percent. This indicates that although a major function of the reader was for scanning purposes (operating time less than 15 minutes), a significant number of users (29 percent) used the viewer for serious study or reading for periods in excess of 30 minutes.

Questions numbered 2 and 3 test user receptivity to the major features of the mini-theater concept. A strong positive response to question number 2 was somewhat anticipated, and the tabulated responses leave little doubt that the mini-theater offers a significant improvement in creature-comfort over standard microfilm viewers. The comments below capture the delighted appreciation of some users.

> ". . . how about a coffee machine — or even free coffee!

> "Would (also) like an ashtray, footstool and stereo."

> "This machine is an extravagance. Nice but hardly necessary."

> ". . . This is so comfortable that I felt like sleeping."

The responses to question 3 indicate that the negative psychological factor of distant viewing of enlarged text, which is contrary to common reading habits for most users, is outweighed by positive psychological factors, perhaps typified by the comments:

> "Like TV and movies — now study!"

> "It's <u>fun</u> to use."

> "FUN!"

The small percentage of negative and indifferent responses to question 3 may be attributed to negative psychological and physical factors in addition to the one mentioned above as the following users' comments show.

> "Feels funny — seemed to strain — reading while seated looking forward (at a vertical screen) instead of down (at a horizontal screen)."

> "I like sitting at a distance from a large screen for leisure reading (but) I like sitting close to a small screen for technical reading."

> "Disadvantage to a nearsighted person."

More extensive testing of user response would be necessary to determine how many and in what way negative responses are attributable to nearsightedness or related visual problems. Such testing could show, for example, that reducing the viewing distance to 3 1/2 or 4 ft would better accommodate nearsighted users without decreasing the appeal of the system to users with normal vision.

In general, however, the mini-theater has a strong appeal to the majority of users. This type of viewer would very likely encourage the use of microfiche in a library environment. Further, it would seem that mini-theater type viewing systems would be ideally suited for prolonged presentations of audio-visual training material to a single or a few observers; a situation where creature comfort and appeal could enhance the effectiveness of the presentation.

Question number 4 confirms that the various image characteristics are quite adequate, although there is obviously some room for small improvements. The response to question number 5 indicates that users either did not notice or did not consider intolerable the three percent keystoning or distortion. This is an important point, since the compactness of the system is possible only by the oblique projection achieved by tilting the conjugate planes which causes the keystoning or distortion.

User reaction to the non-directional qualities and surface qualities of matte screens is measured by question number 7. It is likely, however, that the ambiguity of the terms "easier on the eyes" and "harder on the eyes" allows for confusing screen quality with image quality. This point is demonstrated by the following: 37 users found the screen easier on the eyes and only one of these 37 found image quality fair or poor <u>and</u> preferred sitting close to a small screen; 8 users found the screen harder on the eyes and 6 of these 8 found image quality fair or poor <u>and</u> preferred sitting close to a small screen. It is plausible that these 6 users are nearsighted and have difficulty reading at viewing distances of 5 or 6 ft. Therefore they judge image quality to be fair or poor, and consequently find the display screen "harder on the eyes" or, specifically, a strain on the eyes. Such a person would also prefer sitting close to a small screen. If these six users were, in fact, nearsighted, then the responses to questions 7 and 4a can be interpreted accordingly.

The performance of the velocity-control system and the position-control system is evaluated by question number 6. It seems that the velocity-control system requires a training period before the user can make optimum use of the device. The data from 40 users is insufficient to quantitatively establish that positive responses increase with operating experience and the questionnaire was not designed specifically to establish a learning time. However, several users explicitly stated that they found the control system easier to use after about five minutes of operation. The major difficulties that users commented on were

encountered when centering a page on the screen, and when locating a remote page. The first of these problems could be ameliorated by changing from a two-speed system to a proportional speed control, or pause-on-frame system and the second by providing a frame-location display.

The position-control system, on the other hand, requires no training period beyond reading the simple operating instructions at the loading station. Since the Microform Service Area at the M.I.T. Barker Engineering Library has several late model microfiche viewers with manually operated pantograph-type transports, it is quite likely that it is these viewers that the users are comparing to the vertical-screen viewer. In this case, the position-control system of the vertical-screen viewer represents a significant reduction of user effort compared to the finest manual systems. In any case, the user preference for the position-control system over the two-speed velocity-control system is clearly demonstrated.

Finally, a number of users comments are reproduced below since they contain useful suggestions.

> "Writing table would be helpful."
>
> "A device is needed so an individual can make selected hard copies from the microfiche."
>
> "Screen (clamping glasses) has lots of dirt marks on it — also, is it possible to position (the fiche) so that two full pages are available (for simultaneous viewing)?"
>
> "Difficulty in reading vertical (90 deg rotated) diagrams."
>
> "Inconvenient to have to get out of chair to load (microfiche into the viewer)."

CHAPTER VI

HAND HELD VIEWERS

A. INTRODUCTION

A lightweight, portable, self-powered and hand-holdable microfilm viewer could be an important factor in promoting general user acceptance of microfilm. Such a viewer could be used in a comfortable easy chair, at a desktop, in a plane, bus, and so forth, in short, could free the user from special environments such as libraries or reading rooms. Two major physical problems must be suitably solved in designing a hand-held viewer, namely: power consumption, and device weight and dimensions. Ideally, a hand-held viewer would either utilize ambient illumination, or operate for at least a few hours on a few small rechargeable batteries. Device weight and dimensions should be on the order of a reasonably sized book, so that the viewer is easily carried in a book bag or an attaché case, and is not cumbersome to hand hold.

The technology of fiber optics was investigated since fiber optics offer the potential of reduced device dimensions through high density packing of the optical path. Fiber optics can also be used in a viewer using ambient illumination only. The ability to utilize ambient illumination not only eliminates the need for light sources and power supplies, but implies that image contrast is independent of ambient illumination level, a highly desirable feature.

Photochromic materials were also investigated since the image retention characteristics of a photochromic display screen offered the possibility of viewing with ambient illumination and invariant contrast. Finally, conventional projection optics were re-examined, and a viewer design was evolved which utilizes rechargeable batteries and a conventional tungsten-filament source, and satisfies the packaging requirements for easy portability. Since, however, several viewers that employ conventional optics are presently on the market, or shortly will be, the decision was made to concentrate efforts on non-conventional approaches.

The results of these investigations are presented in this chapter, but the conclusions based on these studies did not warrant the detailed design or construction of a working hand-held viewer.

B. PHOTOCHROMICS

Photochromic materials contain "color centers" that are changed chemically by irradiation with light such that the transmission of visible light is altered. These color centers are activated or made less transparent when exposed to ultraviolet radiation and are bleached by infrared radiation, but are essentially unaffected by light in the

center of the visible range. One concept utilizing photochromics is shown in Fig. 6.1. An ultraviolet source is used to illuminate the microfilm, and the projection lens images the microimage on a photochromic display screen. The infrared source is located off axis and

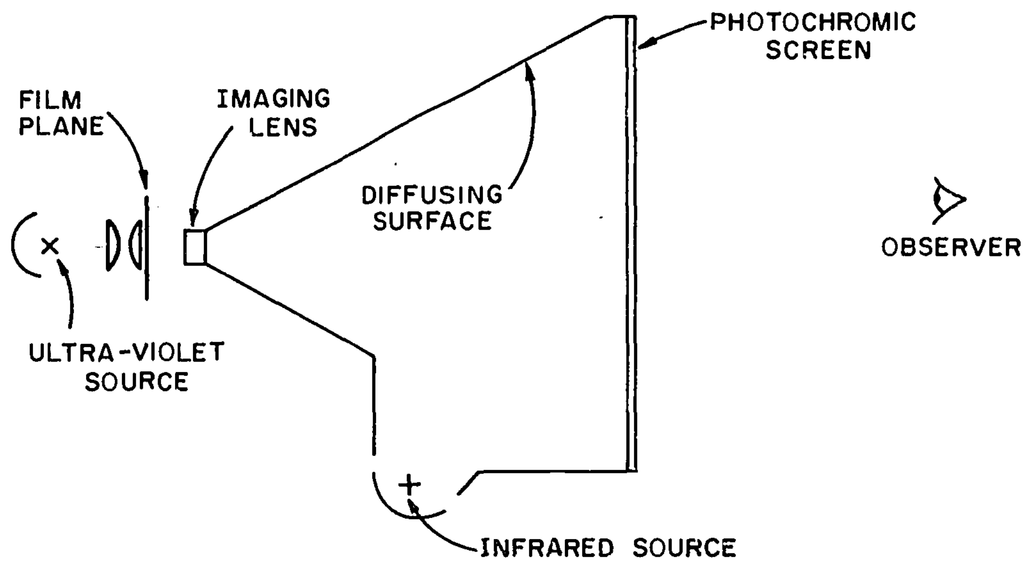

Fig. 6.1 Proposed Viewer Configuration with Photochromic Screen

directed at the screen. For negative microfilm, the photochromic image would be a positive, or dark letters on clear background. This would allow sufficient ambient illumination to pass through the display screen and illuminate the diffusing interior surfaces. These interior diffusing surfaces are necessary to provide a ground against which to view the image formed on the photochromic display screen. The ultraviolet and infrared sources can be pulsed, so that activation and bleaching times are minimized. Filters that might be necessary to protect the observer's eyes from the high-intensity, pulsed infrared and ultraviolet radiation are not shown, but would be located on the observer's side of the screen.

The characteristics of a number of photochromic materials were studied. One glass and several types of film were examined, and some tests were made on one of the films. No materials were found which had characteristics suitable for the application considered here.

The photochromic glass, manufactured by the Corning Glass Works, requires bleaching and activation energy densities prohibitive for use in a hand-held, self-powered viewer. Typical bleaching and activation energy densities are, respectively, 1.0 Joule/cm^2 and

0.2 Joule/cm^2 for a fivefold change in transmission.[5] For a 9 in. x 12 in. display screen, a fivefold change in transmission would require 138 Joules for activation and 690 Joules for bleaching. For 10 percent efficient ultraviolet and infrared sources, the electrical input energy required for scanning of images or repetitive activation and bleaching, would be far greater than could be obtained from a reasonable number of storage cells.

Secondly, photochromic glass cannot achieve good resolution as a display screen for textual images. The resolution determined by the size of the color centers is on the order of 100 Angstroms, and hence is not a problem in a display viewed by the unaided eye. Smaller diameters cannot be activated and larger diameters scatter the light (and hence degrade resolution) that enters the glass. Resolution is limited by the 3-mm thickness of glass required to obtain a transmission ratio of 10 to 1 for bleached to activated areas. A 3-mm thickness would produce imaged characters with a depth equal to the screen depth of 3 mm. This would clearly make reading extremely difficult.

Data on some organic photochromic films were obtained, and a few tests were made to determine their characteristics. The films studied were American Cyanamid Company types 43-540, 43-540A, 51-142, and 63-071, this latter type having the most data available.[6,7]

Since these films have a thickness on the order of 0.003 in., the "three dimensional" aspect of image characters is removed. Resolution of these films is typically quite high, and on the order of 1,000 lines/mm. However, none of these films have sensitivities that are sufficiently high to be of use in a self-powered unit; for example, type 63-071 is optimally activated by an argon ion laser delivering 0.47 Joule/cm^2 in 1.3 msec.

Reference 8 states that this film does not lose its photochromic response when cycled for 20 times to an optical density of 1.8 and then bleached by heating. However, Reference 5 warns that the activation and bleaching cycles produce a gradual reduction in photochromic response. The decrease of photochromic response with use is speeded if the bleaching and activation energies are supplied to the film by high power sources (short pulse duration). In our laboratory tests, a 500-watt light source was used for activation and the response was observed to decrease after as few as eight cycles.

It was concluded, because photochromic materials have one or more of the drawbacks of high activating and bleaching energy density requirements, poor resolution (photochromic glass) when used as a display screen and fatigue (organic photochromic films), no practical viewer design could evolve through use of photochromic display screens.

C. FIBER OPTICS

Fiber optics depend upon the physical phenomenon that light is totally reflected at the boundary between two materials of different refractive indexes if the path of the light is directed so that it would pass from the material of high refractive index to the material of low refractive index and if the angle of incidence at the boundary is sufficiently high. Optical fibers normally consist of an inner core of high refractive index surrounded by a cladding of lower refractive index to produce the total reflection. The entire fiber is often coated with opaque material to prevent stray light scattered by an imperfection in one fiber from entering another fiber. Because light transmitted by fiber optics must have a minimum angle of incidence with the side of the core, there is an angle of acceptance at the end of the fiber within which light must fall if it is to be transmitted by the fiber. Similarly, there is a cone which contains all light which leaves the fiber at the other end. For circular cylindrical fibers, the acceptance angle and the maximum output angle are equal.

Only bundles of fibers that have the same relative position of fibers at the two ends of the bundle (coherent fibers) can be used to transmit images. Such bundles can be more efficient in collecting light transmitted by a film than are most lenses because the bundle end can be placed in contact with the film, and thus all transmitted light that falls within the angle of acceptance of the fibers is used. The resolution of such a coherent bundle of fibers is obviously equal to the spacing between fiber centers, provided the fiber diameter is significantly greater than the wavelength of the light being used to avoid diffraction effects.

For high resolution applications it is necessary at the present time, at least, to use glass fibers. Glass fibers are available in diameters below two microns, although this is a lower practical limit for optical fibers because undesired wave phenomena occur when the fiber diameter approaches the wavelength of the light (0.3 to 0.7 microns). Most glass fibers used in high-resolution work have diameters between five and ten microns. Plastic fibers are available with diameters of 0.005 and 0.010 in. (127 microns and 254 microns respectively), and therefore do not yield high resolution.

Light loss in fiber optics is caused by entrance and exit reflections at the ends, scattering due to imperfections within the fibers and at the boundary with the cladding, and by attenuation of the glass or plastic itself. The packing fraction — the ratio of the area of the fiber cores to the total bundle area — also accounts for a significant loss. Typical glass bundles transmit 70 percent of the incident light for an extremely short bundle. Transmission drops to 50 percent for a 5-ft long bundle and to 30 percent for a 10-ft long bundle.* The attenuation of plastic fibers is somewhat higher.

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* Bendix Mosiac Fabrications Division Data Sheet No. 115.

Coherent tapered optical fibers bundles can be used to magnify images simply by admitting light from the image at the small ends of the fibers and observing the light that emerges at the large end of the fiber. Tapered fibers used in this way have the characteristic that the angle of emergence of the light is less than the acceptance angle of the fiber because of the change in angle at each internal reflection from the fiber wall. This characteristic may be important in some applications.

A microfilm viewer can, in principle, be made by using only a bundle of tapered fibers, as is sketched in Fig. 6.2. This device is not practical because the fiber optics bundle would be quite heavy and extremely expensive, if indeed it can be made by existing means. It will be discussed to illustrate some important characteristics of fiber optics, however. Light from the source passes through the condensing lens and on through the film image to be magnified to the tapered optical bundle. Distance between the film and the fiber optics is kept small. The bundle magnifies the film image by the ratio of the diameter of a fiber at the large end to its diameter at the small end. The resolution of the device, as with all fiber optical systems, is determined by the diameter of the fibers themselves. If the large end of the bundle is required to have a resolution of seven line/mm, (3 1/2 line pairs/mm) and if the microfilm reproduction has a reduction of 20 times,* the fiber diameter at the small end cannot exceed 14.3 microns (0.00056 in.) or 286 microns (0.0112 in.) at the large end. The region in which the image can be observed will be small because of the limited angle of emergence of the tapered optical fibers. The dimensions of the permissible viewing region can be increased by applying a diffusing coating to the bundle output surface, with a resulting decrease in image brightness.

A reduction in the cost and size of the fiber optics bundle can be obtained by the system shown in Fig. 6.3. Here only part of the total magnification is produced by the tapered fiber optics and the remainder by the conventional projection lens. The projection lens would image the bundle face on the screen (see Fig. 6.3).

Even with the limited magnification of this system, the cost of the fiber optics bundle is quite high. We were quoted a cost of $1,500 for a 3X magnifier using tapered fibers measuring 10 microns at their small ends and a size sufficient to cover one 11 mm x 14 mm fiche image. It is true that if these magnifiers are mass-produced, the cost should decrease, but it is not likely that this reduction would

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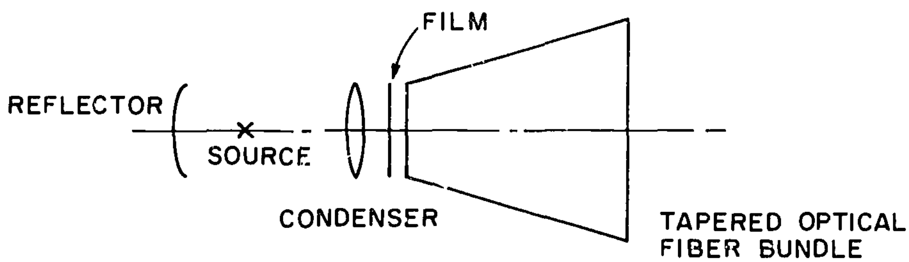
* This is the standard reduction for COSATI microfiche.



Fib. 6.2 Simple Tapered Fiber-Optic Bundle used as Magnifier

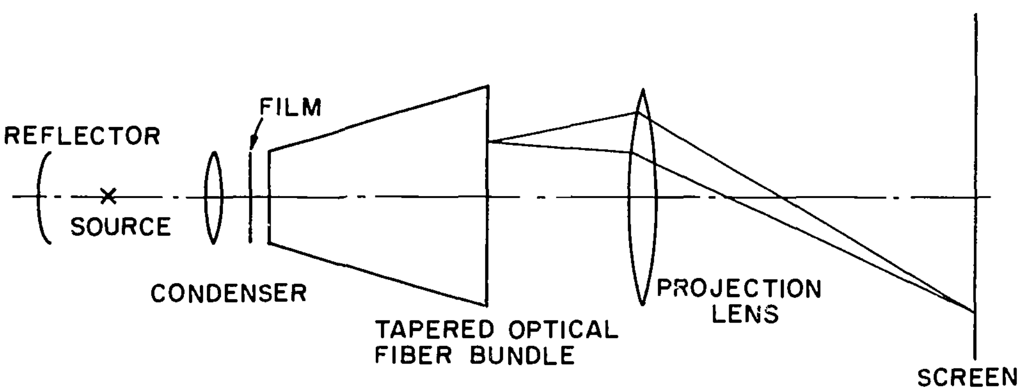


Fig. 6.3 Viewer with Limited Tapered Fiber-Optic Magnification

be sufficient to make the total cost of the optics of the combined system of Fig. 6.3 comparable to that of a single lens that produces a magnification of twenty.

A variation of this system is one that reverses the magnification system by producing the first magnification with a lens, projecting an image on the small end of the fiber optics bundle (diffusing coatings may be required on either or both ends of the bundle, because of the limited entrance and exit angles of the fibers) and viewing the image after it emerges from the large end. This, of course, would require a much larger fiber optics bundle, and hence would be even more expensive.

One other use of fiber optics was considered. It is possible to use, in connection with a fiche viewer, incoherent flexible fiber optics to illuminate the fiche and coherent flexible fiber optics to transmit the image to an imaging system. The size of each bundle need be only large enough to cover one fiche image. The light source, the viewing screen, and the fiche would remain stationary. Different fiche images would be projected by moving the ends of the fiber optics bundles adjacent to the fiche, like an "optical stethoscope". A simplified schematic of a system of this type is shown in Fig. 6.4. The primary advantage of this system is that there are essentially no restrictions on the relative positions of the source, fiche, and screen. In fact, the source and screen can be moved relative to the fiche while the viewer is in use.

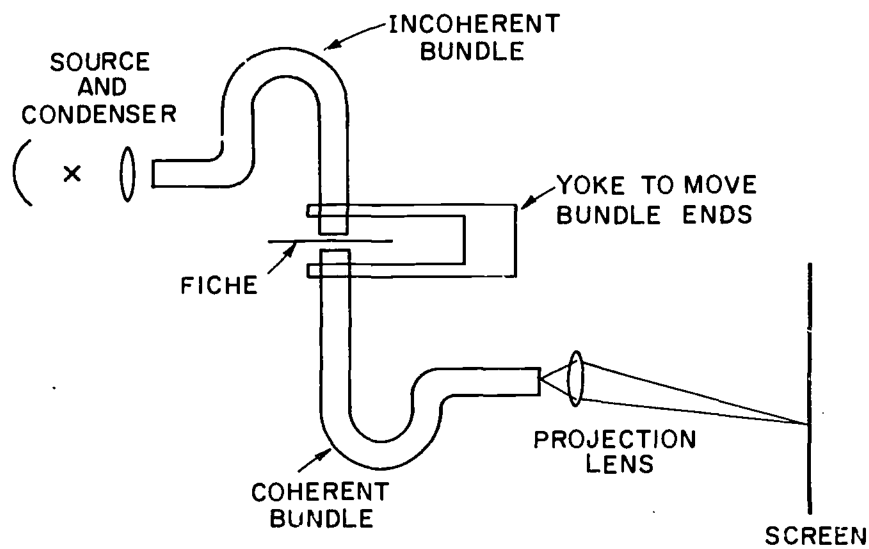


Fig. 6.4 Viewer with Flexible Fiber-Optic Bundles

The major disadvantage of this system is the high cost of the coherent flexible optics bundle between the fiche and the projection lens. A quoted cost for such a bundle of 10-micron fibers arranged in a 12 x 17 mm format was $5,000. The cost of the incoherent bundle would be small by comparison. Since the optical components other than the flexible fiber bundles required by this system are identical with those required by a conventional optical system, its cost would be greater than the cost of a conventional system by the price of the fiber optics. This appears to be a high price to pay for position flexibility of the viewing screen. The use of plastic fibers because of their lower cost is ruled out because of their large diameter and resulting low resolution.

D. CONVENTIONAL OPTICS

Lap-held, portable microfiche viewers were studied to determine the desirable characteristics of such a device. The general arrangement and optical paths of a few possible configurations were determined. No detailed design of the portable viewer was made because of time constraints. However, cardboard models of the viewers were made to obtain a concept of the viewer size and shape and to determine whether or not the viewer could be handled easily.

The basic purpose of the study was to obtain a better portable viewer than those available; many available viewers leave much to be desired, although they are being steadily improved. The viewer was designed to use COSATI format microfiche and to have the following characteristics:

1. Light weight and small size so that it can be used on a desk top or held in one's lap comfortably.

2. Provide approximately 18X magnification as standard, or possibly both 18X and 24X.

3. Light source to have adjustable intensity. Rechargeable batteries to be included in the viewer so that it can be used without external power for an interval of approximately one hour.

4. Fiche transport to be easily manipulated.

5. The screen (back-projection type) should have no scintillations, and should either be sufficiently bright or protected by polarizing plates to be readable with normal ambient illumination.

6. At least 2/3 of a page should be displayed at one time on the screen.

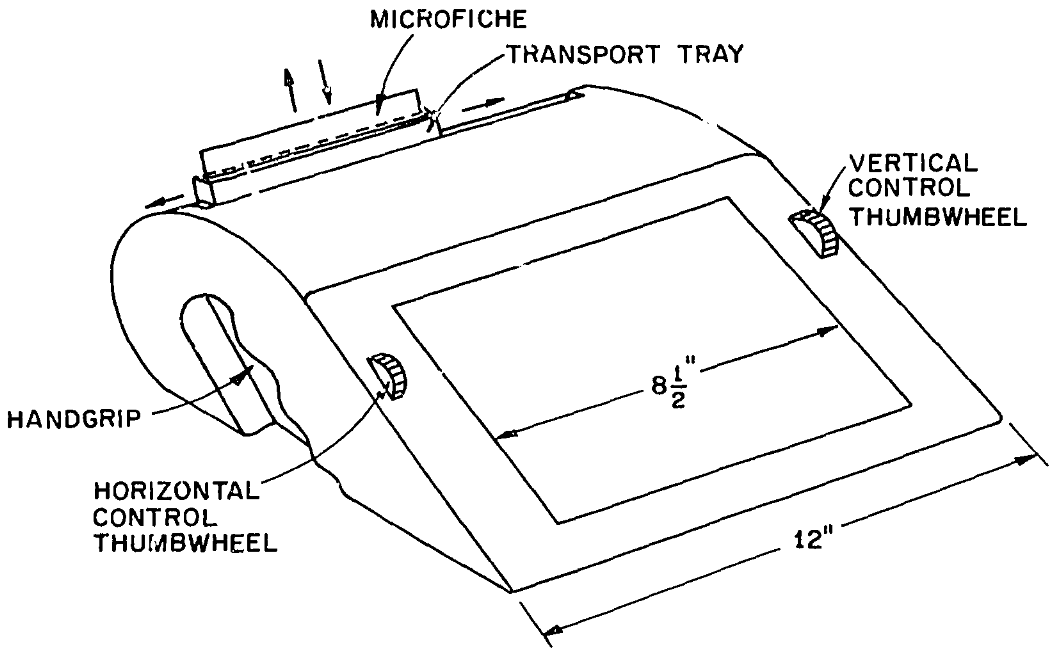
Most of the design effort went into determining the packaging of the components and the resulting viewer shape, because it is the shape of the viewer that largely determines the acceptance of a lap-held reader.

The design study showed that a viewer that is thin in the direction normal to the reading surface is preferred. This characteristic makes the device easier to hold while reading, and more easily handled while being carried than a cube- or hibachi-shaped device. It is interesting to note that the range of preferred thickness of the viewer was not very great; as the thickness increased from 2 in. to 4 1/2 in., users' descriptions of it changed from acceptable and "booklike" to unacceptable and "boxlike".

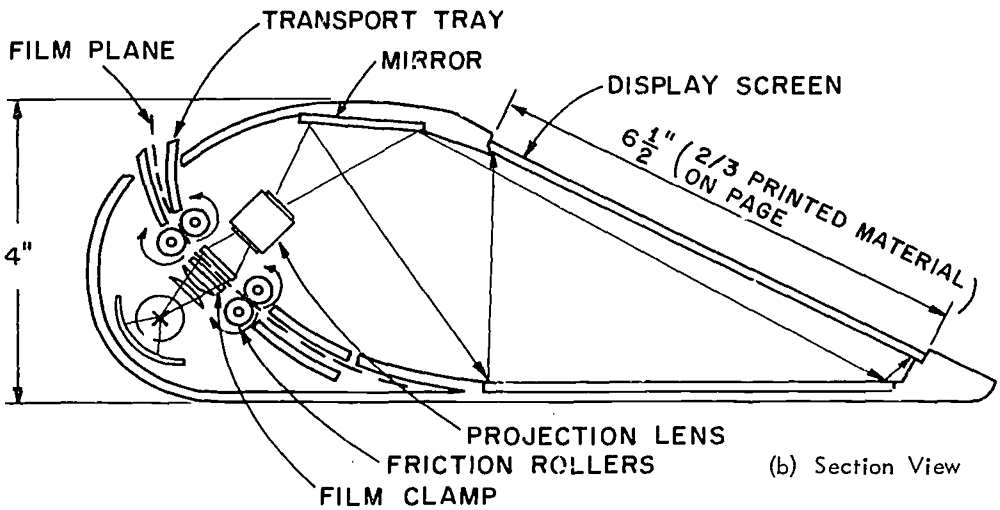
One arrangement presented here is for a 2/3 page display, the fractional page size being chosen to keep the device thickness as small as possible. A convenient fiche manipulator would partially compensate for this less-than-full page presentation. The arrangements considered include the optical components, fiche transport, and power supply (6 D-size cells, transformer, and auxiliary electrical equipment). The optical paths are necessarily folded to keep the viewer size small, and designing the mirror system for folding the path was quite tedious until it was found that the unfolded path of the extreme rays for the optical system could be sketched, the resulting shape cut out like a pattern, and the pattern literally folded. By this means it was possible to quickly try a large number of mirror arrangements for a variety of projection lens focal lengths.

Two solutions are presented here which have acceptable shape and size. Figure 6.5 shows a viewer which is mechanically simple. The 8 x 9 1/2 in. image to be read is presented on a sloping screen by rear projection. The fiche is transported through a carriage by rubber rollers, similar to the transport of paper through a typewriter, and the carriage moves to index the film in the orthogonal direction. Fiche motion is controlled by the thumb wheels at either side of the projection screen. The optics are relatively standard. Light from the source passes through the condenser to the fiche. The fiche image is focused on the screen; the light path is folded twice by means of front-surface mirrors. Batteries, transformers, etc., can be contained in the space that is close to the lamp and is not traversed by projected light. Batteries and a lamp can be selected which make reading possible for approximately one hour with no external power. The cutouts on the sides are for handling. The sloping front makes reading easy whether the device is placed on a desk or held in the lap. The thickness is greater than optimum, but will not be objectionable. A circular polarized plate in front of the screen will probably be required to improve image contrast if the viewer is to be used in the presence of normal room illumination.

Figure 6.6 shows a viewer with a screen that can be folded down so that a compact box is available when transporting the reader,



(a) Front View



(b) Section View

Fig. 6.5 Lap Held Viewer with Fixed Screen

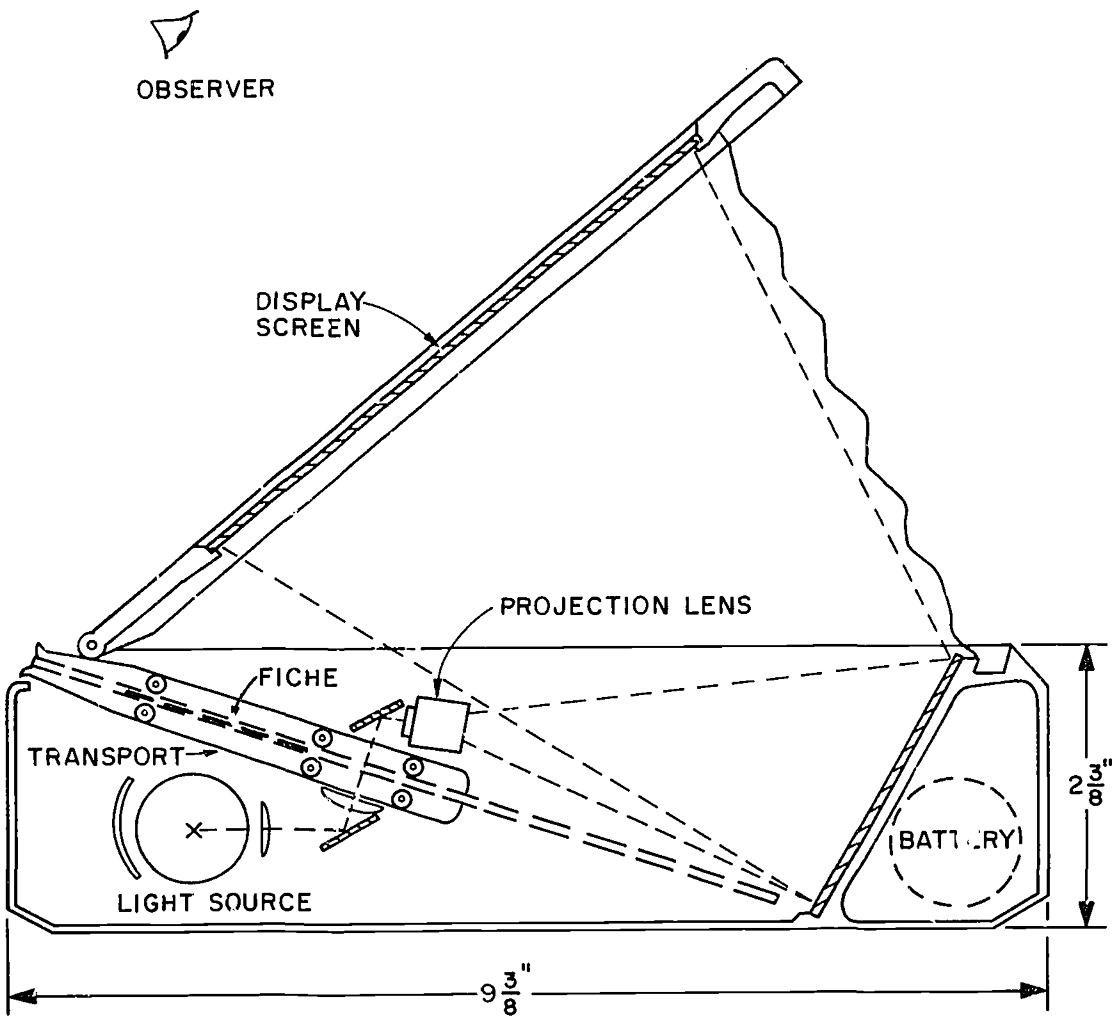


Fig. 6.6 Portable Viewer with Folding Screen — Section View

only 2/3 of a page is imaged at once on the back-projection screen. The fiche is held between two glass sheets which are moved by the fiche manipulator. Folded optics are again used — in this case both before and after the projection lens. A bellows is attached to the screen to prevent dust from falling on the front-surface mirrors when the screen is in viewing position. Batteries and electrical equipment can be mounted in places not traversed by the optical path.

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APPENDIX A

DISTORTION-FREE THREE-LENS PROJECTION SYSTEM

First, an expression is derived for the transformation of the microfilm original to its distorted image. Only the distortions in the plane of the page are considered, the distortions into the plane of the page (z-axis) are discussed later. The general arrangement of the lens system is shown in Fig. A.1.

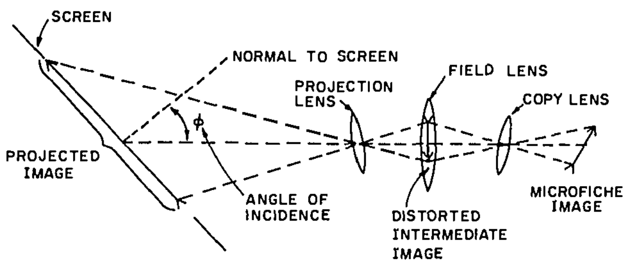

Fig. A.1 Projection System Using Field Lens

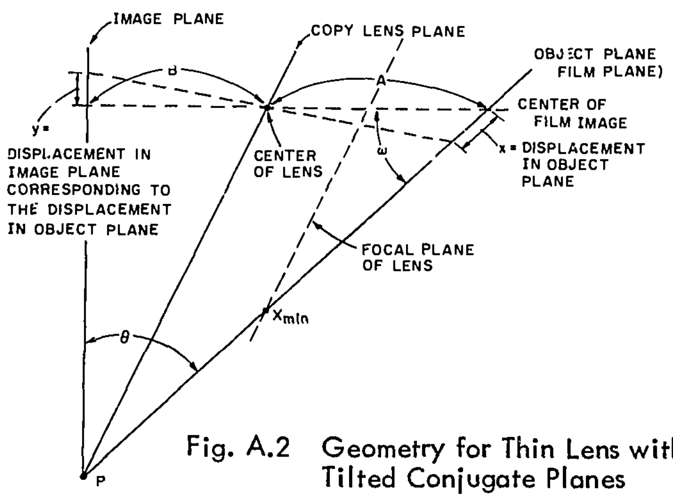

Fig. A.2 Geometry for Thin Lens with Tilted Conjugate Planes

Assumptions: For the copy lens system see Fig. A.2.

1. A, B are conjugate distances.

2. Thin lens assumption that the lens plane, object plane and image plane converge at P.

3. Only small displacements about x = 0 are considered, i.e., $x > x_{min}$.

Then, from simple geometry, $y = \dfrac{B\, x \sin\omega}{x \sin\theta + A \sin(\omega + \theta)}$

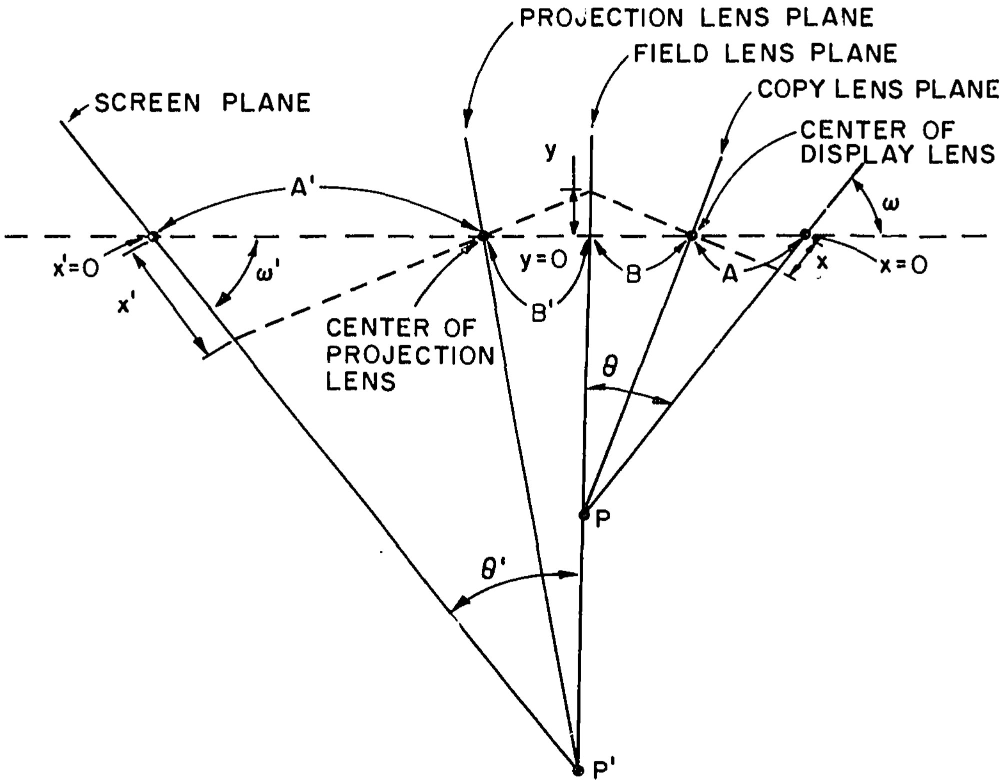

Fig. A.3 Geometry for Composite Scheme

Then, for the composite system (here the field lens is ignored since it does not alter the geometry discussed). (See Fig. A.3)

Obviously, $$y = \frac{B' x' \sin \omega'}{x' \sin \theta' + A' \sin(\omega' + \theta')}$$

Now, for an undistorted image we want $x' = Kx$ (K = constant) for all x. Solving for x' we write:

$$\frac{B' x' \sin \omega'}{x' \sin \theta' + A' \sin(\omega' + \theta')} = \frac{B\, x \sin \omega}{x \sin \theta + A \sin(\omega + \theta)} \qquad \text{(A.1)}$$

and $$x' = \frac{B\, x \sin \omega\, A' \sin(\omega' + \theta')}{B' \sin \omega'\; x[\sin \theta + A \sin(\omega + \theta)] - B\, x \sin \omega \sin \theta'} \qquad \text{(A.2)}$$

For $x' = Kx$, the condition $B \text{ sine } \omega \sin \theta' = B' \sin \omega' \sin \theta$ substituted into Eq. A.2 above yields:

$$x' = x\, \frac{B \sin \omega\; A' \sin(\omega' + \theta')}{B' \sin \omega'\; A\; \sin(\omega + \theta)} \qquad \text{(A.3)}$$

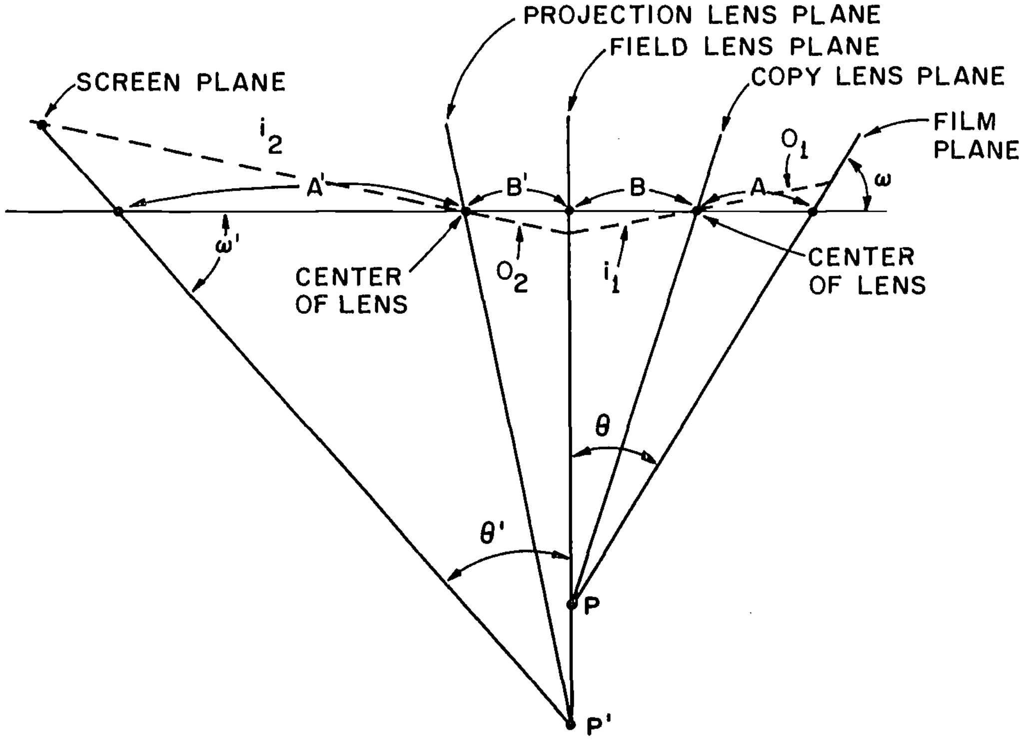

Fig. A.4 Geometry for Composite Transverse Magnification

Finally, distortion along the z-axis is examined to see what further conditions are necessary to guarantee distortion-free images. (See Fig. A.4)

Magnification along the z axis is the simple transverse magnification determined by the familiar expression

$$m = \frac{i}{o}$$

The total M from the film plane to projection plane is $m_1 m_2$ where $m_1 = \frac{i_1}{o_1}$, $m_2 = \frac{i_2}{o_2}$. This yields:

$$M^2 = \frac{(B^2 + y^2 + 2By\cos(\omega+\theta))\ (A'^2 + x'^2 + 2A'x'\cos\omega')}{(B'^2 + y^2 + 2B'y\cos(\omega'+\theta'))\ (A^2 + x^2 + 2Ax\cos\omega)} \qquad \text{(A.4)}$$

In order for M = K independent of x, we require $B' = B$, $\omega' = \omega$ and $\theta' = \theta$. These conditions substituted into Eq. A.3 yield

$x' = x\frac{A'}{A}$, and into Eq. A.4 yield

$$M = \frac{A'}{A}$$

since $\frac{x'}{x} = \frac{A'}{A} = \frac{z'}{z} = M$, the final image will be undistorted and enlarged by M.